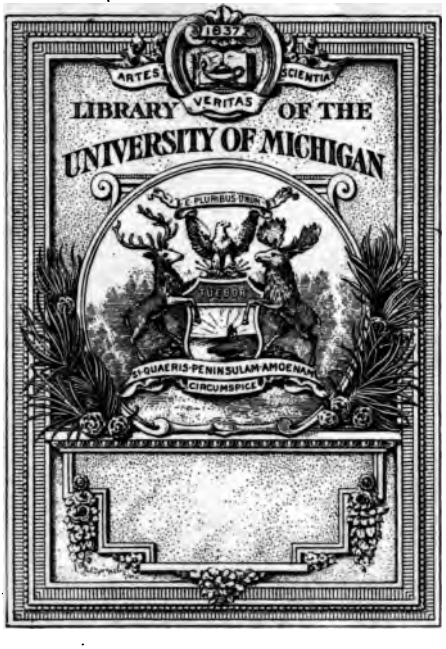
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GRANITE BOULDER (west side of) LYING 1½ MILES NORTHEAST OF LANCASTER, O.

The Cause of The Glacial Period

Being a Résumé and Discussion of the Current Theories to account for the Phenomena of the Drift, with a New Theory by the Author

BY

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PREFACE.

The evidence which has been observed and collected indicates that at some time in the past a large portion of the Northern Hemisphere of our globe has been ground by moving ice—glaciers. In fact, the evidence of this is so conclusive that few intelligent persons hesitate to accept it as a proven fact; but when it comes to accounting for this, then scientists differ from one another. Although many theories have been brought forward to explain the cause of the Arctic climate necessary for such glacial action, and to account for the motive or propelling power in the ice to produce such effects as have been observed, yet none of these theories have received universal indorsement.

While one eminent scientist will present one theory and advocate it with all the zeal and ingenuity at his command, claiming it affords a complete, rational and plausible explanation of all the phenomena usually attributed to the Glacial Period, another with equally eminent attainments will take the opposite view and claim it does not explain all the phenomena; and, furthermore, say that it would be a great misfortune to science should this theory come to be universally accepted. With such difference of opinion among men equally eminent in

science, the question as to what caused the Glacial Period may be regarded at the present time as an open one, or by no means a settled one.

The author, after having read the discussions of the various theories that have been brought forward from time to time to account for the phenomena of the drift, has been impressed that the key has not been found, or, at least, has not been presented, that will unlock the mysteries of the Glacial Period. Causes other than any which have been suggested will have to be sought.

It is pretty generally admitted that the same forces we observe at work upon the earth to-day have been with us ever since the planet had its birth. No new laws have been introduced. The processes of nature are universal and unchangeable. This being true, it seems to me that the so-called Glacial Period ought not to be relegated to the category of mysteries, but by a careful study of the laws of nature, should be rationally accounted for. Hence it is to assist in unraveling this mystery that this little volume has been written.

When the author first began to read on this subject, he had a preconceived opinion of the cause, which to him seemed so reasonable that he wondered why others had not come to the same conclusion and adopted it to the exclusion of other theories. He thought there must be some defect in this theory which he was not able to see, and he longed to read a scientific discussion of it, that he might have the

defects, if any, pointed out. With that end in view, he read everything on the subject that came into his hands, but so far has been disappointed. He has not found a single author who maintains or even discusses this theory; therefore, so far as the author is concerned, this theory is original. However, it may not be new; probably others have advocated the same, and their arguments may have been refuted; but as none of the other theories have received universal acceptance, there is still an opportunity for this one.

It is hoped that a perusal of these pages may be interesting, even if not convincing, to such as have preconceived opinions in favor of some other theory.

With that hope in view, and with only a desire to arrive at the truth, I remain,

Yours truly,

H. L. TRUE, M.D.

McCONNELSVILLE, O., OCTOBER, 1902.

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CHAPTER I.

DESCRIPTION OF PHENOMENA.

Over nearly all the northern portion of the United States east of the Rocky Mountains there are found erratic stones of foreign origin, known as bowlders. They vary in size from small pebbles, usually called gravel, to stones of immense size. In some places they are mixed with the clay, in others they are found in beds along the streams. These latter seem to have been rolled to their present position by the streams in the vicinity of which they are found. Such is probably true; but where did the streams get them?

Upon examination of the ledges of rocks along the streams to their source, no such stone is found. They have come from some place beyond the sources of the streams. Professor Wright found, back of Covington, in Kentucky, conglomerate bowlders interlaid with pebbles of red jasper. These bowlders were so characteristic in appearance that he determined to search for the ledge from whence they originated. On one of his geological excursions into the northern part of Canada he found many

outcroppings of the same kind of rock. He collected specimens and turned them over to his students for examination, and from comparison with other specimens which had been collected from different parts of Ohio, they were able to trace a line of the bowlders from the parent ledge in Canada clear across Ohio and into Kentucky ("Man and the Glacial Period," p. 64). Now what was the agency which scattered those bowlders?

MOHEGAN ROCK, NEAR NEW LONDON, CONN.
From Wright's Ice Age, by courtesy.

GLACIAL STRIÆ AND GROOVES FOUND IN MORGAN CO., O., SOUTH OF THE MORAINE.

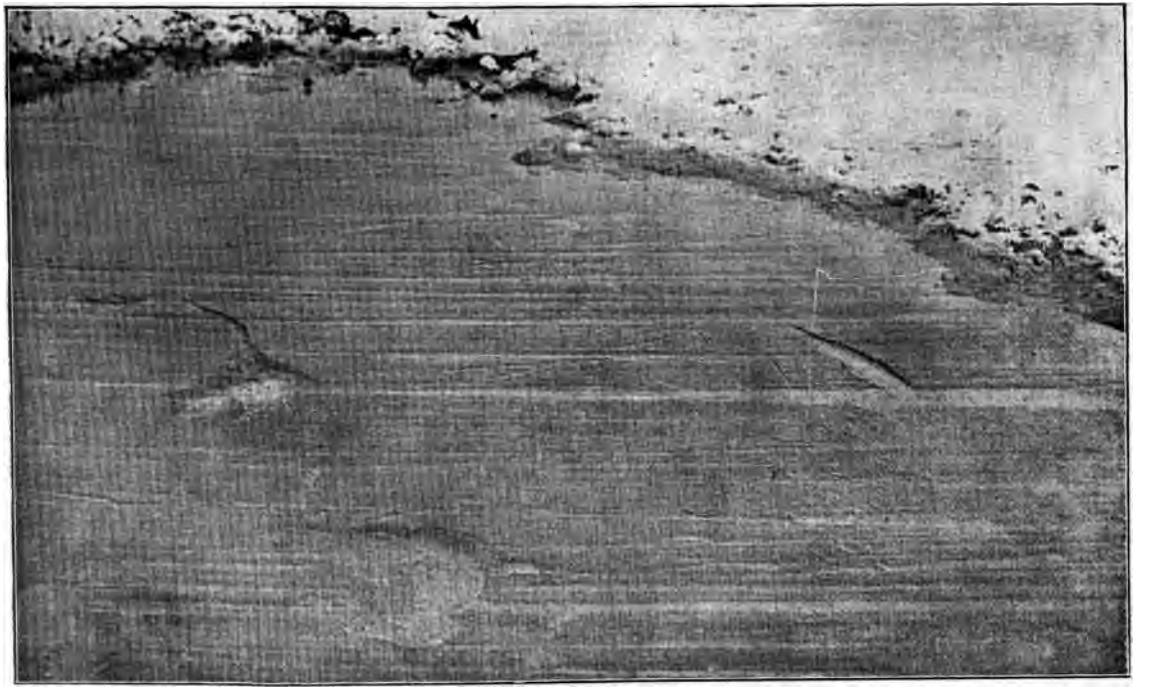
In some places huge bowlders weighing many tons are found in isolated positions, notably near Lancaster, Ohio. Professor Andrews describes a granite bowlder eighteen feet long and sixteen feet wide lying in the valley northeast of Lancaster, Ohio. (See frontispiece.) Also one measuring seven feet across and almost on the top of a hill two hundred and fifty feet above the large bowlder just referred to, which lies near the base of the hill. (See "Ohio Geological Report," Vol. XI., p. 442.)

"The largest bowlder yet described in New England is Mohegan Rock, in the town of Montville, New London County, Conn. Its dimensions are as follows: Length at eastern side, fifty-four feet; southern side, seventy feet; western side, fifty-six feet; northern side, fifty-eight feet; height, sixty feet. The weight has been estimated at ten thousand tons."

"Plymouth Rock is a bowlder from the vicinity of Boston, having accomplished its pilgrimage long before the departure of the Mayflower from Holland." (Wright.)

The author has observed bowlders as large as haystacks in isolated positions on the prairies of Illinois. What was it that placed these stones in such isolated positions?

The surface of such bowlders is usually smooth, rounded, and they have the appearance of having been worn smooth by rolling. Some of these stones are striated, with the appearance of having been pushed along, or scratched by some other substance



GLACIAL STRIÆ FOUND IN AMHERST, O.

From Wright's Ice Age, by courtesy.

equally hard. Some show a rough side where they have been broken off, while the rest of the stone is smooth. The broken side of the bowlders had the appearance of having been broken by some great force acting upon them while they were in a fixed position. What was it that broke these stones?

In many places in the above mentioned territory, usually spoken of by geologists as the drift region, underneath the clay the bedrocks show scratches, straight lines and furrows; they are grooved, and these grooves usually run parallel and in a southerly direction, although in detached rocks sometimes another set of grooves cross the first set at various angles, as if the second set had been made after the stone was detached. The surface of some of these grooves is highly polished. They are usually found in the hard bedrocks underneath the clay in the drift region, such as the Trenton limestone. The softer rocks of the Coal Period do not preserve them. What made these furrows?

Over a greater portion of the drift region, hills are leveled, valleys filled, rocks detached, transported and left promiscuously mingled and in all positions.*

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* Professor Newberry has estimated the area south and west of the Canadian highlands covered with glacial debris (loose material) at about one million square miles. The average depth he estimates at thirty feet. Professor Claypole has estimated the thickness in Ohio, Indiana and Illinois at sixty-two feet. Professor Orton, from reports from the boring of one hundred and twenty-two oil wells in different

What was the agency that accomplished all this?

All these phenomena and many more are common over the drift region. They have attracted much attention. As the evidence of the drift is well described in all the standard works on geology, a further description of them will not be necessary in this connection.

Many theories have been brought forward to account for the drift phenomena. Some have but little foundation in reason. I have, therefore, arranged them under the head of Curious Theories. The consensus of opinion at the present time is to attribute these phenomena to glacial action.

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counties in Ohio, has calculated the average depth at ninety-three feet. The deepest found was in Champaign County, where five hundred and thirty feet was bored, and the well abandoned before rock was reached.

The fine, loose material found over the drift region, such as the various kinds of clay, sand, etc., appears to have been made from soft rocks, such as shale and sandstone, while the bowlders are generally from very hard rock, such as granite and quartzite. The probabilities are that for every one of them which is observed over the drift region, thousands have been ground to powder by the same agency which pulverized the softer rocks and smoothed the surface of the bowlders.

The gravel banks along the streams are composed of what is called assorted drift materials—*i. e.*, the finer particles of sediment have been washed out and carried away by the water. The larger particles, such as sand, gravel and bowlders, have been gathered and rolled to their present positions by the streams.

CHAPTER II.

CURIOUS THEORIES TO EXPLAIN THE PHENOMENA.

When the phenomena described in the preceding chapter began to be observed, many theories were proposed to account for them. Some of these theories had a foundation in reason, while others were so crude that they could hardly be called theories; as, for instance, some people see nothing unusual in the scattered bowlders. They believe God created them just where we find them, and they say it would be no more difficult for him to make a bowlder than to make any other stone. Others attribute them to the Noachian deluge; but as they do not tell us where the deluge got them before distributing them, it has been facetiously suggested that they are thunderbolts and hailstones which fell during Noah's rainstorm, for it is reputed to have rained *hard* at that time.

Some think that they were made from sand by the action of running water rolling them over and over, receiving accretions from time to time — a process similar to that of making large snowballs by rolling. It is cited in support of this, that bowlders are usually found in the neighborhood of large streams. Another explanation somewhat similar to this is, that they are concretions made from substances formerly

held in solution by the water, deposited by some chemical action between the substances in solution and the sand.

Some think they are made from detached fragments of ordinary rock, rounded by rolling over and over by the water in the streams. Some think they originated at the bottom of the ocean, having been made from angular fragments of detached rock, smoothed and rounded by the waves rolling them over and over. This was done while this country was all under water. A modification of this idea is that they were shore pebbles, formed along the beach of some ancient ocean, and that they were rolled and rounded by the action of the waves.

As the bowlders are usually of different material from the native ledges where they are found, being characterized by extreme hardness, this fact gave rise to the idea that they were of igneous origin. One theory proposed is that they were ejected from volcanoes in a molten state, and, falling into water, were cooled quickly — tempered as metallurgists temper metal. Thus they account for their hardness, but where the volcanoes are that ejected them none of the advocates of this theory have been able to determine. Others have thought they are meteoric stones — having originated some place beyond the earth's atmosphere, and, coming in contact with it, were, by friction against the atmosphere, smoothed and hardened as we now find them.

One recent author has sought in a very ingenious

manner to prove that the so-called glacial deposits are simply so much meteoric matter which had formerly floated in a stream or orbit around the sun, and with which the earth accidentally came in contact.

All the foregoing theories are ingenious and will do for speculation, but, unfortunately for them, the bowlders have been proven to have come from rock upon the earth. As, for instance: many of the bowlders in Ohio and Pennsylvania have been traced to their sources in Canada and Ontario.

The first theory that gained much consideration in the scientific world is called the diluvial theory. By it, it was thought that at some time in the past a great tidal wave swept down from the north, bringing death and destruction with it, engulfing everything and bringing the drift with it. In this way were accounted for the remains of extinct animals that were found buried in caves and in various places in the drift. This theory received a " backset " when it was shown that the amount of erosion, leveling of the hills and the transportation of rocks could not have been done by a sudden tidal wave. The theory was abandoned, but the name diluvium, or drift, which came with it, has remained, and loose materials in the glaciated region are still called by that name.

Next came the iceberg theory. It had a greater run than the preceding, and it still has some advocates among scientific men. By it, it was supposed that all the drift country was submerged and polar currents floated down icebergs from the north, loaded

with materials of the drift, and melting during their progress into a warmer latitude, strewed the drift along their course and striated the rocks at the bottom of the sea by the fragments which were frozen into them. It was claimed by the advocates of this theory that a similar process is now going on in Baffin's Bay and along the banks of Newfoundland. It will be seen that this theory involves both submergence and iceberg agency.

The next theory that I shall mention is called the earthquake theory. This theory supposes that the drift countries were submerged, and that their central regions were subject to violent earthquake shocks and elevations oft repeated through a succession of ages; that these convulsions propelled over the northern portions of the globe enormous waves, which bore along from the polar regions immense icebergs and strewed the pre-existing loose materials of the earth far to the south of their former positions; that immense masses of such materials received the impulse of the earthquakes and acted upon the rocks beneath to produce the erosion that has been observed. (Gray.)

I have only presented the foregoing theories as curiosities. None of them have many advocates at the present time. As before stated, the consensus of opinion now is to attribute the phenomena of the drift to the action of glaciers, a description of which process will be given in the next chapter.

In the ice fields of Greenland, the slope of the moving ice is estimated at one degree, or seventy-five feet, to the mile, while in the Antarctic Continent it is believed to be only one-half degree, or forty-five feet, to the mile — a slope so small as to be scarcely appreciable to the eye.

Such an ice sheet as either of these would have been sufficient to produce the phenomena seen in the drift region of North America.

Many people have a very erroneous idea of the way the glaciation was done in the drift region. The usual idea of a glacier is a body of ice sliding down a valley. Such a conception comes from pictures taken from Alpine glaciers. But the glacier that produced the drift of North America was not of that kind. It was a continuous ice sheet, extending from the Atlantic to the Rocky Mountains, and several thousand feet in thickness. Such a mass, in its forward movement, stops not on account of hills or valleys that cross its way, but goes right over them, tearing the tops from the hills and filling the valleys, either with debris from the hills or broken ice from the glacier.

The surface of glaciers usually is strewn with loose fragments of detached rock, which have been torn from ledges by which the glacier has passed, and underneath it are other loose materials, consisting of fragments of stone, gravel, sand and clay, all of which, being pushed along by the glacier, acts as a "mighty rasp, or, rather, a combination of a plow, a

A GREENLAND GLACIER.

From Geikie's Great Ice Age.

rasp, a sandpaper and a pumice stone, plowing, scraping, scratching and polishing the surface all at the same time" (Wright), and rolling, rounding and smoothing the fragments of stone underneath the glacier, converting them into bowlders, etc.

When a glacier does not reach the sea, but terminates on the land, at the place where it melts there is an accumulation of the loose materials which have been transported by the glacier. This accumulation is called the terminal moraine. At the end and below the glaciers of the Alps, and also some of those in Alaska, can be seen all the effects of glaciation, such as rounded bowlders, striæ and grooves in the bed rock, which we know were made by glacial action; and, they being so similar to those in the drift region, we can almost say they furnish a positive demonstration of the manner in which these latter were made. In fact, the terminal moraine of the glacier that once covered the northern part of the United States has been traced from the Atlantic to the Rocky Mountains. Also, the terraces along our streams furnish positive evidence of the great floods that swept down as the ice was thawing out. The same is being formed by the streams that put out from the glaciers of the Alps.

Several theories have been proposed to account for the movement of glaciers, and much investigation has been carried on endeavoring to demonstrate the real cause of their motion. The consensus of opinion is that ice is not an inflexible solid — that it acts

something like resin or pitch endowed with a plasticity, gradually flowing down a declivity and molding itself to the general outlines and contours of the valley through which it moves, flowing faster at the surface than at the bottom and sides. If we consider ice plastic, a body of it piled high enough in a plain, or even in a depression, would cause the center to settle down and the sides to spread or even move upwards over inclines. It would move towards the point of least resistance. The above described theory is the one most generally accepted among scientists. Others have gained some advocates, but, as they are well described in the standard works on geology, I will not burden the record by describing them.

The fact is proven that great bodies of ice on land will move with almost irresistible force — will move in the direction of least resistance, whether that be up an incline or down a slope. We have to recognize this fact, whether we can rationally account for it or not; and, knowing that ice does act in this way, as can be seen by going to the places where such bodies exist, all we have to do to account for the drift phenomena is to suppose that such an ice sheet as now covers Greenland and the Antarctic Continent once covered the drift region of North America. If we can get such a body of ice as above described, we can account for the drift, but when we come to account for the climate that would cause such a body to form and proceed far into the temperate zone, we find another and more difficult question. Prof. Le Conte

says this is one of the most difficult questions of geology.

It is supposed at one time the drift region was possessed of the rigors of an Arctic climate, which lasted for a geological age. Many theories have been brought forward to explain this. These theories can mostly be arranged into three separate classes, viz.: Those which involve great geographic changes in the contour of the country; those which attribute the climate to secular astronomical changes, and those which assume a change of the earth's axis, each of which classes will receive consideration in separate chapters.

CHAPTER IV.

THEORIES INVOLVING GEOGRAPHICAL CHANGE.

As Alpine glaciers only move along a descending slope, it was supposed, when it was first suggested that the drift phenomena might have been produced by glaciers, that this region must have had a similar slope to have caused the glaciers to move. Therefore, there must have been a great elevation toward the north of the North American Continent. As elevation is accompanied by decreased heat, as is seen on lofty mountains, it naturally would be suggested as the cause of the frigid climate. The two seem to go together, and this theory, with modifications, has been held by some eminent scientists ever since drift phenomena began to be studied.

The advocates of this theory have a fact to assist them, which seems almost sufficient to furnish a demonstration that such northern elevation did exist, and that is this: the direction of the grooves and striæ and the transportation of materials have been principally toward the south, or in a southerly direction, thus demonstrating that the movement was from the north.

Although the advocates of this theory have never been able to tell us exactly what caused the elevation sufficient to produce a glacial period, yet some of

them have been able to tell us what caused the ice to disappear. It came about in this way: The overload of ice caused the surface to bend beneath it and settle down, the effect of which was to modify the climate and cause the ice to thaw out. Then, after being relieved of its load, the surface partially raised again, but not to the extent it was when the ice was forming.

It was objected to this theory that, to give a slope sufficient for glaciers to move several hundred miles, as must have been done in this case, would have required incredible elevations; as, for instance, a moderate slope of two and one-half degrees, continued for two hundred miles, would produce an elevation of nearly nine miles. But when it was found that the glaciers of Greenland and Antarctic Continent sometimes move on a slope of only forty feet to the mile, this objection disappeared.

The evidence, as furnished by nearly all the standard text-books on geology, proves conclusively that during the glacial period there must have been northern elevation of the district covered by the glaciers. So strong is the evidence of this that nearly all the other theories or other causes which have been suggested to account for the glacial period are coupled with it. I do not object to the claim that there was a northern elevation, and for the present am willing to admit that such really existed; but the weak place in these theories is that they do not explain what caused the northern elevation. If the reader will

bear with me until I come to that point, I will try to account for it.

Another theory closely connected with this one, and usually presented with it, is that of the shoaling of the North Atlantic and the diversion of the Gulf Stream from the polar regions. As the North Atlantic is very shallow for an ocean (being nowhere between Scotland and Iceland more than six thousand feet in depth, and mostly but six hundred feet — Dana), a slight northern elevation would bring the bottom above water level; hence, these theories are closely connected, or one is part of the other, and if the Atlantic was shoaled and the gulf stream diverted southward, a glacial period in the northern hemisphere would result. That conclusion is inevitable; but what shoaled the Atlantic?

The next theory is similar to the last. It supposes a sinking of the Isthmus of Panama and Central America, thereby allowing the warm water of the Gulf of Mexico to flow across into the Pacific Ocean, thereby diverting it from the northern regions by the way of the gulf stream, and turning it into the Pacific Ocean. As a depression of seven hundred feet would suffice to bring the most of this region under water, it seems to me it has been suggested because the originator thought it would be easier to sink the Isthmus of Panama than it would be to raise the bottom of the North Atlantic; and, as either would produce the effect desired, he chooses the one that could be done with the least disturbance to the gen-

eral contour of the earth. Hence, he takes "the isthmus route." But, as the evidence seems to indicate that the isthmus has recently been under water, we will not fall out with the advocates of this theory about this route.* But what sank the isthmus and raised it again?

Prof. F. W. Very has suggested that the glacial period might have been produced in this way: First: "There existed polar land rings, limiting the ocean, polewards, and preventing the wholesale refrigeration of the great masses of the ocean by icy water from the polar seas." Second: "The subsequent sinking or removal of the barriers."

No doubt that barriers across the ocean, shutting out tropical currents, would have a marked effect upon the climate of the polar regions. The water north of such barriers would become chilled, and probably if this condition lasted long enough, the polar ocean would freeze to the bottom, while the water on the south side of such barriers, having free circulation with tropical regions, would become very much warmer than it now is. This increase of temperature would make greater evaporation, and the increase of cold on the north side of the barrier would

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* "Dr. G. A. Maack, in his report upon the explorations for a ship canal across the isthmus, represents the evidence as indicating that the isthmus was covered by the sea a comparatively short time ago, and of the fossils as being such as are still living in the sea. This formation seems to extend all over the isthmus."—Wright.

favor precipitation. These are favorable conditions to produce a glacial period; but Prof. Very attributes the warmth of the Tertiary Period to these very conditions. His language is as follows: "The existence of these great volumes of warm water, sending up their perpetual clouds of vapor, would so modify climates that it is quite possible that the winter cloud-caps might protect even the polar regions from any large refrigeration, and thus give the conditions of a warm and moist atmosphere over Greenland, whereby a luxuriant Tertiary flora was enabled to flourish just before the great climax which revolutionized climatic order. The conditions which had endured for ages were reversed; the polar land rings began to subside; the alteration of polar and equatorial winds, which had been held in check by the former disposition of land and sea, broke out with violence. By degrees the poles were cooled, and the icy waters produced began to flow out and take the place of the warm waters of the temperate and tropical seas. It would take a very long period of time to displace the immense body of warm water accumulated in these seas, and during this process we should have just those anomalous conditions needed to produce the huge ice deposits of the Glacial Age, viz., local cold, due to the sweeping away of the protecting cloud-caps of the polar zones, and the intimate juxtaposition of an almost limitless source of water vapor. A steaming ocean and a frigid land surface furnish

the requisite conditions for a perpetual distillation as long as the supply of water holds out."

According to Prof. Very, the Glacial Age did not begin until the polar land rings began to subside, and the icy water from the polar regions began to flow out and the tropical currents began to flow in. It was during this mixing process, which lasted a long time, that the Glacial Period occurred; but when the waters were thoroughly mixed, the Ice Age passed away. This strikes me as a curious way to produce a Glacial Period. It seems more likely that such a process would end one than to produce one. The Professor says: "The completion of the oceanic transformation marks a new era — and the glaciers recede." What kind of logic is this? If the complete mixing of the waters causes the glaciers to recede, it seems reasonable that a half-way mixing would modify the climate to a certain extent, and so on backward. The climate would modify just in proportion to the progress of the mixing of the cold and warm waters, which would come together as a consequence of the sinking of the land rings.

It is a demonstrated fact that nearly all the water of the ocean below the four-hundred-fathom line is chilled down to near the freezing point of fresh water, and sometimes below it, by the polar currents which have crept under. (Cold water is more dense than warm water, and will displace it.) In fact, there is now in the bottom of the oceans cold sufficient to

produce a Glacial Period nearly all over the earth, if the cold water was on the surface; but, fortunately, it is covered by a stratum of warm water. Investigation by soundings has demonstrated the low temperature of the deep water of the open ocean all over the world. At first this was thought to be the natural condition of water at great depths, but a further investigation showed that it is from the cold arctic currents that have crept under, for it is found that where a reef or ridge shuts out the cold water from the polar regions, the deep water does not show the low temperature as other places do. By this variation of the temperature of the deep water, ridges across certain portions of the ocean have been located. The deep water of inclosed seas like the Mediterranean does not show the low temperature like that of the open ocean. It is evident that, if any barriers were to be thrown across the oceans which would prevent the cold water from distributing itself over the bottoms of the oceans — confine it in the polar regions — then a Glacial Period would result; but it would surround each pole, instead of confining itself to one side of one pole, leaving the other side unglaciated, as seems to have been done during the Glacial Period. And then again, what would make such barriers across the oceans? Prof. Very says they had existed for ages, but just before the Glacial Period "the conditions were reversed"; *i. e.*, "the polar land rings began to subside." Now, it seems strange that this

subsidence should occur simultaneously in both hemispheres, which would be necessary to produce the effect claimed to be the cause of the Glacial Period.

There is no doubt that land barriers existed which prevented the warm water of the oceans from going to the polar regions, and if the reader will bear with me until I come to that point, I will explain them. Furthermore, it does not seem improbable that the refrigeration of the deep waters of the oceans is closely connected with the disappearance of the ice over the glacial region. The warmth of the water was extracted in melting the ice. In other words, the cold of the so-called Glacial Period has been transferred to the deep waters of the oceans. Could we make an accurate estimate of the refrigerated water in the depths of the oceans, it would be found that the earth had gained nothing since the Glacial Period in the sum total of its heat, but, on the contrary, it has been continually losing it. The entire mass of the earth is cooler now than it was at any time during the Glacial Period.

It is easy to see how a refrigeration of the deep waters of an ocean might end a Glacial Period on land adjacent to it, but not so easy to see how it could produce one, for in this case you simply transfer the cold of the land to the water in the bottom of the ocean.

The iceberg theory mentioned in chapter second supposes a sunken condition of the whole drift region

and a transportation of the drift materials by icebergs from the far north. What would sink the drift region and then raise it again?

To me any of the theories above enumerated seem insufficient to account for a Glacial Period. In the next chapter the Astronomical Theories will be considered.

CHAPTER V.

ASTRONOMICAL THEORIES.

Several theories involving astronomical changes have been proposed to account for the climate of the Glacial Period; as, for instance, it has been suggested that there may be colder and warmer regions in space through which the solar system in its movements has to pass. According to this theory, the warmth of the Tertiary Period was produced by the solar system passing through a warm stretch of space, and the Glacial Period by passing through a cold one.

This is a beautiful theory, and if we only knew that such warm and cold regions exist in space, we could account for the climate of the Glacial Period easily; but, unfortunately, there is no proof to sustain it.

It has been suggested that in the lapse of ages our sun, with his planets, might have passed so near some other star as to have experienced an increase of heat from the proximity. Might not variations of climate upon the earth have arisen in this way? It is easy to conceive, if such a condition should occur, the temperature might be increased, but it is not so easy to conceive how such a proximity might make a Glacial Period; but astronomers will not admit the possibility of our sun approaching so near some other star

as to affect the climate of our globe; therefore, this has been abandoned.

Another theory supposes our sun to be a variable star, deriving its heat from falling meteorites. By this theory it is assumed that our sun passed through a stretch of space during the Tertiary Period where the meteorites were in abundance, and it therefore derived great heat from them, causing the warmth which geologists tell us existed at that time. Then again it passed a stretch where meteorites were few; therefore, it derived but little heat from them. Thus the theory accounts for the cold of the Glacial Period.

Another theory supposes that during the Glacial Period the surface of the sun was in a great measure obscured by an enormous sun-spot, supposed to be a piece of dross floating on its surface, preventing the sun from radiating its usual amount of heat. After accumulating for a long time, this dross finally sank beneath the surface, and then the sun warmed up again.

Major General A. W. Drayton claims that the earth has another motion — that the precession of the equinoxes indicates in reality a very slow revolution of the earth from north to south — that the drift region was glaciated while it was passing the point in space now occupied by the polar regions, which regions are now being acted upon by the ice in a manner similar to the way the drift region was subjected while it was passing that point.

It has been suggested that a comet might have

become entangled and journeyed with the moon about the earth and produced the Glacial Period. Or it might have been "the interposition of a cometary mass between the earth and the sun, the comet or meteoric swarm revolving for a time in an orbit about the earth, and its shadow covering certain regions which thence became glaciated." The rings of Saturn have been cited as furnishing an illustration of "the actuality of such companionship of a planet and a cloud of cosmic dust." The matter of such rings might have been attracted to the earth, and thereby furnished the glacial deposits; or it might have been gathered together and formed the moon; or it might have got loose from the influence of the earth and then went on its way.

"There are some who think the Ice Age has arisen from the interchange of position between land and water on the earth. There are some who assert that the Ice Age was caused by excessive heat, just as there are others who say that there was never any Ice Age at all." (Sir Robert Ball.)

Some have thought the Glacial Period was caused by a change of the earth's axis. Prof. Newberry classes this idea with other "mere efforts of the imagination, which are not only destitute of all proof, but . . . also of probability." (Ohio Geol. Survey, Vol. II, p. 66.) I hardly comprehend the meaning of this statement. If by a change of axis is meant a change of obliquity, or the angle which the equator makes with the ecliptic, we have proof that such does

occur. As a matter of fact, there is a secular change constantly going on in this obliquity, but it is so slight as to make only a difference of about fifty seconds in a century, or about one-half second in a year. At present it is diminishing, and will continue for some thousands of years, when it will vibrate back again to its former position. Astronomers have calculated that this change can never amount to more than one and one-half degrees from the present position, or two or three degrees in the whole vibration.

Now, this change in obliquity of the ecliptic which is known to be going on has been seized upon by glacialists as having been a probable cause of the Glacial Period. Mr. G. F. Becker has ably maintained this theory, and Prof. Croll also uses it to assist his theory based upon the eccentricity of the earth's orbit. Others have thought the change produced by this variation would be so slight as to have no appreciable effect upon the climate of the earth.

Probably Prof. Newberry has reference to such theories as suppose a greater change in the obliquity of the equator to the ecliptic than the variation which is known to be going on. Some have supposed that some time in the past a great catastrophe overcame the earth, which caused a marked change in its axis, and the Glacial Period was in some way connected with this catastrophe. There are several theories which involve something of that kind, and the arguments to support them are so ingenious that I deem them of sufficient importance to be given considera-

tion, which I shall do in a future chapter. The hypothesis that a change in the earth's axis, giving a greater obliquity between the equator and the ecliptic, would produce a Glacial Period, will also be discussed in a future chapter.

The great astronomical theory that bid fair for a time to supplant all other theories, in accounting for the Glacial Period, is that of Sir James Croll. As this is the theory principally relied upon by scientists to-day to explain the Glacial Period, a separate chapter will be devoted to it.

CHAPTER VI.

CROLL'S THEORY

Of all the astronomical theories to account for the climate of the Glacial Period, that of Prof. James Croll, of Glasgow, Scotland, seems to have been received with the greatest favor by geologists and physicists. In fact, many think it affords a " rational and plausible explanation of many things that heretofore were regarded as inexplicable and altogether mysterious."

Croll's theory attributes the climate of the Glacial Period to the " combined influence of *precession of the equinoxes and secular changes in the eccentricity of the earth's orbit.*"

It is a fact well known to astronomers that the orbit of the earth is not an exact circle. It is slightly elliptical, and the amount of eccentricity varies or changes gradually during long periods of time. At present the earth in mid-winter is in the point of its orbit nearest the sun (perihelion), and consequently is three millions of miles nearer the sun than in mid-summer; but, owing to the precession of the equinoxes, it is gradually changing its position in its orbit in reference to any particular time of the year. In ten thousand five hundred years it will be in the most distant part of its orbit (aphelion) in the winter time. The earth moves more slowly while in a distant part

of its orbit than while nearer to the sun; consequently it would make the winters longer than at present, and colder, but this difference would not be sufficient to produce a Glacial Period. Prof. Croll recognized that fact himself. He and Mr. Stone, of the Greenwich Observatory, calculated the eccentricity of the earth's orbit through several millions of years, both forward and backward from the present time. It was found that the greatest eccentricity was about two hundred and forty thousand years ago, when the earth would be nearly fourteen millions of miles farther from the sun in winter than in summer. This, he claims, would reduce the mean annual temperature of London forty degrees — amply sufficient to produce an arctic climate.

There is another factor which Prof. Croll has cited as materially accentuating the effect of precession of the equinoxes. That is the change in the obliquity of the equator to the ecliptic, as explained in chapter five.

The idea set forth in Croll's theory is this: If we can find the time when the earth's orbit was the most stretched out into an ellipse, and then put the earth in the most distant part of this ellipse, in the winter time, we will get the most favorable condition for an extremely severe winter; and that is what Prof Croll and Mr. Stone have done. Then, having found the time when the winters were the coldest, they suppose that so much ice was accumulated that the short summers would be insufficient to dissipate it. It was

carried over from year to year, receiving each year additional accumulations. As the position of the earth would change, bringing it nearer the sun in the winter the climate would moderate somewhat; but, owing to the great eccentricity of the earth's orbit, the large accumulations of ice during these cold periods would be carried over to the next period of aphelion winters, when it would receive additional accumulations. Thus he thinks that cold periods occurred regularly every ten or twelve thousand years, but at much longer intervals, on account of the increased eccentricity of the earth's orbit, they were extremely severe. The two combined produced the Glacial Period. He thinks the maximum of this period was about two hundred thousand years ago, and that it existed, with certain alterations, for about one hundred and sixty thousand years, making it about forty thousand years ago since the Glacial Period passed away. (See note, p. 77.)

Now, if all this is true, then there is no need of looking further for the causes of the Glacial Period. Astronomers have solved the question for us, and even fixed the time when the Glacial Period occurred, and all we have to do is to look over their figures and see if they are correct. So positive is Sir Robert Ball that this theory is the right one, that he says: "Perhaps it would hardly be an exaggeration to assert that even if geologists had not hitherto discovered the Ice Age from its records on the globe's

surface, astronomers would have demonstrated by calculation that Ice Ages must have happened, and would even now be urging the geologists to go and look for their traces."

For a time it was thought the question was settled. We had not only the date of the Glacial Period, but from it we had a standard which could be used to measure other geological periods. But objectors have arisen.

If the Glacial Period originated from the causes mentioned above, then we would have a succession of Glacial Periods, for this is a recurring event. After vainly looking for evidence of former Glacial Periods, geologists have failed to find any. So far as the evidence has been investigated, it shows that there was but one Glacial Period,* although in some places

* Some geologists have claimed there were other glacial periods in the past geological history of the earth. As, for instance, Professor Dana supposes an arctic chill came over the waters of the ocean, which exterminated the life of the fauna of the Cretaceous Period, as very few of them survived the transition to the Tertiary Period. Others have suggested that it must have been something like glacial periods thrown in between, which made the transition from one geological period to another. Taking this view of it, it might seem to sustain Croll's theory—that of a succession of glacial periods. Such would be true if these changes came in regular order, but unfortunately for Croll's theory, they do not; and besides, some of the periods as recorded by the rocks must have lasted millions of years, or during many epochs of maximum eccentricity of the earth's orbit, and yet the climate remained nearly the same, as is shown by the fossils.

there appear to have been intermissions in it. This seems to be a point against Croll's theory.

Then, again, if the Glacial Period was produced in this way, why should it not have extended clear around the northern hemisphere? That it does not extend on both sides of the earth is admitted, and this would appear to be a fatal defect in it. However, this has been explained by connecting it with some of the geographical theories involving changes of elevation, as explained in chapter four; and also by the supposed diversion of some of the ocean currents toward the southern which now go to the northern hemisphere. Then, if geographical changes are necessary in order to apply Croll's theory, instead of explaining the Glacial Period he has only complicated it and made it more difficult to understand.

Croll's theory has received reinforcement by the labors of Mr. Wallace and Sir Robert Ball and others, but with all these additions, there are some things about the phenomena of the Glacial Period which it is inadequate to explain, and it is the opinion of some of the most eminent geologists and physicists that it would be a great misfortune to science should this theory come to be generally accepted.

CHAPTER VII.

THE CARBONIC ACID THEORY.

In trying to find a cause for the climate of the Glacial Period, the influence of carbonic acid in the atmosphere has been considered. Prof. Tyndall first suggested that a lessening of the proportion of carbonic acid in the atmosphere might suffice to bring on the cold climate of a glacial epoch. Many other investigators have also thought that the abstraction of carbonic acid should be considered in trying to account for the climate of that epoch. Prof. Willis says: "Carbonic acid and moisture are the effective constituents which thicken, as it were, the atmospheric blanket, and, being warmed, in turn keep warm the earth. If they are decreased, the blanket becomes thin and the surface grows cold."

He thus describes the functions of carbonic acid and moisture in the atmosphere: "They both absorb radiant heat in an unusual degree. By thus raising the temperature of the air, they both increase its capacity for moisture, and they both are chemically active."

Thus it is seen that if the carbonic acid in the atmosphere is increased, the warmth is thereby also increased, and by this the capacity to hold moisture is increased, which in turn also holds radiant heat and assists the warming process.

Under normal conditions at present, the proportion of carbonic acid in the atmosphere is three or four parts in ten thousand; but the evidence seems to indicate that in earlier geological periods the proportion must have been very much greater than at present, as is witnessed by the immense deposits of coal, limestone and other rocks of which carbonic acid enters into the combination. This carbonic acid must have been abstracted from the atmosphere, and the very process of bringing this about must have aided in cooling the earth and changing its climate. It is easy to show that the abstraction of carbonic acid might have assisted in cooling the earth, but not so easy to show how the carbonic acid was returned to the earth when the climate moderated and the Glacial Period passed away. Carbonic acid in the atmosphere, no doubt, has had a marked influence on the climate of the earth in past geological ages, and the amount remaining at present still has a great influence and retards the radiation of heat. It has been calculated that a decrease of sixty or seventy per cent. in the present supply of carbonic acid in the atmosphere would reduce the mean average temperature of the earth eight or ten degrees, which, it is claimed, would be sufficient to bring on a Glacial Period; whereas, an increase of carbonic acid to two or three times its present amount would bring on a mild climate in high latitudes. To have a regular climate during a long geological period would require

that the proportion of carbonic acid in the atmosphere be kept constantly very nearly the same.

It is assumed by physicists that the amount of carbon in the world has been practically always the same as at present. It is distributed in combination through the various crystalline and sedimentary rocks of the earth's crust, and through the water in solution, and in the air as free carbonic acid gas. As chemical action is constantly going on among the elements of the earth, on the one side, and carbonic acid is constantly being released from its combinations and added to the atmosphere, on the other side it is constantly being taken from the atmosphere and entered into new combinations; and the difference between these two processes constitutes the available supply of carbonic acid of the atmosphere. Any change in the activity of chemical processes is liable to affect the supply of free carbonic acid; as, for instance, the disintegration and constant weathering of rocks all over the earth's surface is brought about mainly by absorption of carbonic acid from the atmosphere, which enters into combination with the materials of the rocks, forming carbonates and converting carbonates into bi-carbonates, and then is carried away in solution by the waters into the sea. It is estimated that the amount of carbonate of lime annually carried in solution by the rivers of the world and contributed to the ocean to be two billion, seven hundred million tons. From the ocean it is deposited principally as limestone.

At the present rate of consumption, if there were no source of replenishment, the amount of carbonic acid taken from the atmosphere in the dissolving of the various compounds of silicon in the weathering and erosion of the earth's surface has been estimated to be sufficient to exhaust the present supply of that gas in from five thousand to eighteen thousand years.

On the other hand, the principal supply of carbonic acid comes by the liberation of it from the rocks by the heat generated in the action of the internal forces of the earth — the crushing together of rocks in the upheaval of mountain chains, and the displacement of continents.

It is thought that the amount of carbonic acid consumed in the growth of vegetables and given off by animals and by the consumption of coal is a very insignificant part, and hardly necessary to be taken into account in the calculation, because these processes in a measure balance each other, and they only serve to prolong the time until the water finally gets the carbonic acid and carries it away into the sea. The balancing line between the consumption and the giving off of carbonic acid may be drawn between seismic action in the earth's crust and the weathering of the surface.

Now, to account for the Glacial Period in accordance with the carbonic acid theory, it is assumed that the warmth of the Tertiary Period (which just preceded the Glacial Period) was brought about by the large supply of carbonic acid that was given off in

the seismic action that attended the upheaval of the great mountain chains of the world. Then as the weathering went on (being accelerated by the increased heat) the large quantity of carbonic acid was gradually used up or abstracted from the air, until the air became so poor in carbonic acid that it would not retain heat, and the result was a Glacial Period.

Now, to get the earth warmed up again, as it has since the Glacial Period, according to this theory, it is assumed that when a large portion of the crust of the earth was covered with an ice mantle, weathering would be prevented over at least that portion covered, and chemical action would be retarded by the cold all over the earth. Such a condition of reduced demand for carbonic acid, the supply remaining the same or perhaps increased by seismic action brought about by the bending of the earth's crust from the superincumbent load of ice, would allow the proportion of carbonic acid in the atmosphere to increase, and then the earth got warmer and the Glacial Period passed away.

This theory is ingenious, and it is supported by many able advocates, and while I admit that carbonic acid may have played an important part in influencing climate in past geological ages, and perhaps does so at present, yet this theory is wholly inadequate to account for all the phenomena of the Glacial Period, as I shall show in a future chapter.

CHAPTER VIII.

THEORIES INVOLVING A CHANGE OF THE EARTH'S AXIS.

In examining such writings upon the Glacial Period as have come into my hands, I have frequently found allusions to a theory that supposes the axis of the earth has changed from what it was at the time of the Glacial Period; as, for instance, the one alluded to in Chapter V. by General A. W. Drayton, that the earth has another revolution from north to south. Professor Dana says a change in the earth's axis has been regarded as a source of variation in climate. But calculations by Mr. G. H. Darwin, Haughton and others have shown that no such change can have taken place sufficient for any marked result. (Geology, p. 126.)

I have not been able to find this theory fairly presented in any text-book. Professor Newberry says it has generally been rejected.

I would do justice to this theory if I could get a fair presentation of it, for I believe, although not true, yet it comes nearer the truth than some other theories which have been advocated by some of the most eminent scientists.

The best presentation of it which I have seen is that of Mr. George Neidig in the Pittsburg *Dispatch.* He evidently has given considerable thought to the

subject. I will quote his language, not in full, as I have not space, but sufficient to get his idea of what took place in reference to the earth's axis:

"That the earth in her earlier stages rocked, reeled and rolled, that the igneous crust was repeatedly ground in still mightier cataclysms than the assumed one under consideration, is clearly in evidence, and if in the natural economy there be a plainer, a simpler and a more effectual way of doing this than from the consequences that must ensue from a shifting of the earth's *polar axis*, the writer has failed to recognize it." The way it was done he explains in the following language: "Let us return to the assumed predecessors of the present polar centers. As now, there were developing ice areas. The accretion was slow, but the law that wrought it was never suspended and went on as centuries made ages. . . . An ice cap entirely surrounded by water, may in its extension toward the temperate zone reach the point where wear and tear of warmer wind and wave may balance its accretion and thus bar further growth. Now, if the growth of one ice cap exceeds another, and this excess is continued, is there not a limit set when this excess of weight localized on a revolving sphere will demand readjustment? . . . Is it at all possible for the sphere to continue to revolve around the old centers when they are no longer the centers of gravity? If you affirm that it will, then kindly indicate the law that impels such a

line of action against itself. Does the objector say that the change of the poles would be gradual? . . . This is hardly true in nature. Great operations generally first reach a poise and then act suddenly. Resistance must first be overcome. A tree will not fall a corresponding per cent. to the first stroke of the ax. It may remain standing until one more stroke is decisive. When near the poise a sudden breeze may inaugurate the final act, nor will it commence to fall with a rapid motion."

"An out of balance sphere may be turning as usual, but when near the condition of poise, a small matter may set the surrounding water areas in the favoring direction, and internally and externally the mobile material commences to concentrate, with cataclysmic inundation as the consequence." He says further: "Since a revolving sphere must have a center of motion, where is the warrant for assuming that under changing conditions the centers of motion may not change?" . . .

"The earth may, and probably also did, change the inclination of her axis. . . . No two of the planets are alike in the inclination of their axes to the planes of their ecliptics; and is there any reason for affirming that polar points, once established, must remain so during the duration of the planet?"

"The change of poles that resulted in planting the present centers of motion was the long-continued localizing of ice at the prior poles, one of which,

becoming unduly weighted, at length yielded and caused the cataclysm that destroyed the flora and fauna of a former tropic zone."

Now, if I rightly understand this author, he holds that the earth's axis has changed. In this I have to differ from him. If he means that the matter of the earth has only adjusted itself to the original stationary axis, then we are not so far apart in our views.

The former equator as he points it out is as follows: "Let us trace the remarkable volcanic belt beginning with Mts. Erebus and Terror, on the Antarctic Continent, along the general direction of the western coasts of the two Americas, over Kamtchatka, down the coast of Asia past Japan, and around to the place of starting. This is a volcanic girdle around the globe, the only one of the kind, and physically of exceptional significance. Was it a mere chance that thus disposed three-fourths of the volcanoes and regions of violent seismic disturbance along the line of a mere meridian? Let it now be assumed that this belt marks a former equator, and that this line of volcanic vents was established long ages prior to the drift period. This line as a former torrid zone is much more consonant with the continental areas of land distribution than is the present equatorial line that leaves five-sixths of the land in the northern hemisphere, and the great bulk of water in the southern hemisphere." "Every indication is as if the present equator were arbitrarily arranged." The ancient north pole he fixes in the North Atlantic,

not far from the inlet to the Mediterranean Sea; the south pole, somewhere in the South Pacific, exactly opposite.

Mr. Neidig does not tell us why the primitive equator should be staked off with a line of volcanoes, and I am at a loss to account for it, unless he thinks the crumpling was from the readjustment of the ring that covered the equatorial protuberance of the earth. Of course, when the earth was turned around, or part way around, from south to north, this ring would have to shrink or crumple up in order to make a good fit in its new position over the nucleus; but, to accomplish this, it seems to me that the crumpling should have been crosswise of the ring. In other words, all the mountain chains along the lines of the primitive equator should have been transverse to it, which is not the condition we find. This displacement seems to have been lateral, and hence must have come from some other cause than that of taking up the slack in an equatorial shell. It is plain that the rivers and streams of the earth are mostly flowing in channels that have taken, perhaps, millions of years to erode. If any one will stop and think of this, he will see that such could not be the case had the earth been turned around to the extent as supposed by Mr. Neidig.

The same objection holds good in reference to the theory of General A. W. Drayton, that the earth has another revolution from north to south. If such were true, the streams of the world would soon be flowing backward in their channels, for it must not

be forgotten that the earth is an oblate spheroid. Were the earth turned around, the equatorial protuberance would be a greater elevation than any of the others on the earth's surface, and the streams would all flow away from it.

It is said that some English naval officers, fifty or sixty years ago, from certain pendulum experiments, deduced the theory that they had discovered on the coast of Guinea a place which is fifty miles lower than it should be, on the supposition that the earth is a true spheroid. They jumped to the conclusion that the flat place was the ancient north pole, which the centrifugal force of the earth's rotations had not yet rounded out.

Such observations need confirmation before they will be believed, and such confirmation has not been forthcoming. We will, therefore, have to dismiss this story as a product of pure imagination. *

* Since writing the above the author has listened to a lecture by Professor T. C. Mendenhall, late member of United States Geodetic Survey, and in this lecture he states as fact that scientists hold that there really is a depression of several miles in the waters of the Gulf of Guinea. They account for this depression by the theory that in this locality the water is attracted downward by some exceedingly dense substance underneath. To the writer it would appear that if such dense substance exists, it would pile the waters up above instead of drawing them downward. However this may be, I do not see that it furnishes the key to unlock the mysteries of the Glacial Period, for if this depression is the site of the ancient pole, I see nothing to prevent the waters

Dr. John Evans has made an ingenious suggestion that there might have been a change of latitude on the surface of the earth, brought about in the following manner: The crust of the earth, being a shell covering a molten interior, might have slipped or changed its position without disturbing the axis of motion of the nucleus within. There might have been very considerable changes of latitude, due to upheavals or crumpling of this shell, or removal of land masses between the equator and the poles, and the consequent sliding of the remainder of the shell over the nucleus until the equilibrium is restored. Apropos to this, the Rev. O. Fisher has suggested that the almost universal traces of present or former volcanic action — the evidence from the compressed strata in mountain regions that the crust of the earth must have a capacity for slipping toward certain lines, the great amount of horizontal compression of strata which can be proved to have been accomplished, and the secular changes of climate, notably the former warm climate near the north pole — furnish grounds for inquiry: "Whether a fluid substratum over a rigid nucleus would not be compatible with mechanical considerations, and whether, under these circum-

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rushing in and filling it up—rounding it out as it were How could it do otherwise?

The equator itself is slightly elliptic. The excess of its longer over its shorter diameter is about two miles. (Enc. Brit. Art. on Astronomy.)

stances, changes in latitude would not result from unequal thickening of the crust." (Enc. Brit.)

This theory is ingenious, but the points of evidence cited in support of it are against the theory; *i. e.*, in the connection in which they are cited. For instance, a reference is made to the crumpling of the crust, as is evidenced by the upheavals along mountain chains. If we are going to account for a change of latitude by a slipping of the crust brought about by these upheavals, then the principal mountain chains of the world should have extended in direction east and west. To allow a landslide from north to south, the crumpling and overlapping of strata would have to extend in an easterly and westerly direction; but we do not find this to be the case. The most of the mountain chains of the world extend north and south; therefore, a change of latitude could not have been produced by this crumpling of the crust. If you will reverse the order, and say that the crumpling was produced by a change of latitude of the crust, it might have some foundation in reason. As, for instance, if, from any cause, the shell or crust of the earth should be moved either north or south over the nucleus within, the latter remaining stationary, then this crust would not fit the nucleus. If the change was southward, on one side of the earth there would have to be a stretching of the shell on that side of the earth, to accommodate itself to increased circumference as we approach the equator; on the opposite side there

would have to be a jamming up or crumpling. The stretching, in a southward movement, would probably produce a depression. May be the beds of the ocean were made in that way, and the jamming together in a northward movement would make a mountain chain. Who knows but this is a correct solution of the question as to how the principal mountain chains, continents and oceans came to be extended in a longitudinal direction? This explanation would be all right if the mountains were all on one side of the earth and the oceans on the other side; but, unfortunately for the theory, we do not find them so located; but, on the contrary, they are intermingled on both sides; therefore, we will have to look for some other cause than this to account for their extension northward and southward.

Possibly a very slight change of latitude might be produced by the crumpling in, the upheaval, of a mountain chain, if that chain extended in an easterly and westerly direction, but the maximum of such change could only be equal to the shortening of the crust from the crumpling. It would as likely be manifested in one direction as in another; and in whatever direction the surface should crumple, the change by it would be so slight as to make no perceptible difference in the climate of the earth.

All discussions which the writer has seen as to what would be the effect on climate were the axis of the earth changed, seem to have confused or con-

founded two propositions or merged them into one, viz.: First: A change of the inclination of the axis in relation to the ecliptic; and, second: A change or readjustment of the matter of the earth to its original stationary axis. Both these propositions will receive consideration in separate chapters.

CHAPTER IX.

A CHANGE OF THE EARTH'S AXIS WOULD NOT PRODUCE A GLACIAL PERIOD.

In endeavoring to account for the climate of the Glacial Period, a change of the earth's axis has frequently been suggested as having been a probable cause of it; *i. e.*, it is supposed that during the Glacial Period the axis of the earth pointed in some other direction as regards to space from what it does now, and on account of this changed position of the earth's axis, the Glacial Period resulted.

Before entering into a discussion as to the possibilities of such change of the earth's axis having occurred, it would be well to consider whether, even if it did occur, it would have the effect claimed for it. Would a change of the earth's axis produce a Glacial Period? We will examine the question and see if there is any foundation for supposing the Glacial Period might have been produced in that way.

The earth's axis now stands at an angle of sixty-six and one-half degrees from the ecliptic, or twenty-three and one-half degrees from a perpendicular to the ecliptic. Suppose, now, we straighten it up, making the equator to exactly correspond with the ecliptic and the axis to stand perpendicular to it, or making an angle of ninety degrees with the ecliptic. What will be the result?

On the supposition that the orbit of the earth, the time of the revolutions, both diurnal and yearly, be continued, and the earth have a changed axis, as above described, the result would be that we do away with the changes of seasons, and make the length of the days and nights of any one place on the earth's surface always the same. The temperate zones would have perpetual spring or fall, without any summer or winter. The central part of the torrid zone would be somewhat hotter than at present, while the centers of the frigid zones would be colder than they now are in summer, and warmer than they are in winter. In other words, the climate of the earth would be changed to a more regular climate, not subject to the extremes of heat or cold that we now have, but, on the whole, the same amount of heat would be received from the sun in a year, and, of course, no Arctic climate in the temperate zones could exist. Glacial action might still be continued around the poles, but the frigid zones would not be enlarged, or, at least, not to any great extent. Such a position of the earth would not account for the ice advancing into the north temperate zone down to thirty-seven degrees and thirty minutes, which latitude in Southern Illinois is the point it reached during the Glacial Period. So it is seen that straightening up of the earth's axis would not produce a climate that would allow such an advance of the ice sheet as this into the temperate zone. The Glacial Period could not have come from straightening up of the earth's axis.

What would be the effect were we to incline the earth's axis from a perpendicular in a greater degree than it now inclines, thus rendering the equator more oblique to the ecliptic? Suppose we put the axis down to within twenty-three and one-half degrees of the ecliptic. The equator will then form an angle of sixty-six and one-half degrees with it. What effect would this change have upon the climate of the earth? It would only make a greater difference between the climate of winter and summer. The sun in his apparent northern journey would come as far north as latitude sixty-six and one-half degrees, which would then be the Tropic of Cancer (summer solstice), and in his southern journey he would go as far south as the Antarctic Circle, which would then be the Tropic of Capricorn (winter solstice). The result of this change of axis would be to make very hot summers in the temperate zones, followed by very cold winters; but in the aggregate the earth would continue to receive the same amount of heat from the sun in a year, and, of course, no arctic climate could exist in the temperate zones except for a short time during midwinter, and this would be dissipated by the extreme heat of the following summer.

The ice sheet in Greenland is from three thousand to six thousand feet thick (Nansen, "Nature," Vol. XL., p. 210, 1889), and in the Antarctic Continent it is still thicker. It is believed that the ice sheet which covered the drift region of North America was as heavy or heavier than that of Greenland. As the

annual precipitation of snow is limited in amount, it must have taken some thousands of years for such an ice sheet to form, and its formation would have been impossible in a climate possessed of an extremely hot summer, which would dissipate all the ice formed by the preceding cold winter.

Thus it is seen that by tipping the earth's axis nearer to the ecliptic, we only make a greater contrast between the seasons; but we can never make a Glacial Period in the temperate zones in that way.

What would be the effect were the earth's axis inclined toward a point in the southern heavens instead of toward the northern, as it now is? In that case you only reverse the seasons in reference to time; *i. e.*, the winters of the calendar would be changed into summers, and *vice versa*, but no Glacial Period in a temperate zone would result from such a change.

In like manner you may tip the axis in any other direction than those above indicated, and you may thereby change the seasons, but the earth will still continue to receive the same aggregate amount of heat in a year from the sun, and consequently can have no glacial accumulations in its temperate zones, provided always that the time of the revolutions and the earth's orbit remain unchanged.

To make a Glacial Period in a temperate zone by a change of the earth's axis, you will have to suppose a wabbling or unsteady motion of the earth in its orbit — you will have to suppose that the axis points in one direction as to space while on one side of the

sun, and in an opposite direction while it is on the opposite side of the sun, so that the same hemisphere of the earth would be always turned away from the sun. This would make an arctic climate on that hemisphere, while the other hemisphere would be possessed of a torrid climate, and yet the total amount of yearly heat received from the sun would remain unchanged. But what would produce such a wabbling of the earth in its orbit as would be necessary for the conditions of a Glacial Period? Would it be from an accumulation of ice in the polar regions sufficient to change the center of gravity of the earth? We will suppose it that way. We will suppose that a changed center of gravity would cause the earth to wabble in its diurnal rotations, in the same way that a top will wabble when loaded with lead on one side. What effect would that condition have upon the climate of the earth? The earth wabbles down and then wabbles back again once in twenty-four hours, but is receiving all the time the same amount of heat from the sun that it did while it had a steady motion. The effect of the wabbling would be to distribute the sun's heat more generally over the earth's surface than is done under the present conditions. It would be like a boy turning in succession every side to the fire in order to warm himself. Such a wabbling could never produce a Glacial Period, provided always that the time of the rotations of the earth and its orbit remain unchanged. To produce a Glacial Period by wabbling, we will have to suppose a semi-yearly

wabble; the axis will have to point in one direction while on one side of the earth's orbit, and in another direction while on the opposite side. The precession of the equinoxes is, in miniature, just such a wabble as we are trying to get, and is supposed to be produced by the piling up or bulging of the earth at the equator, but the wabble only amounts to about fifty minutes of longitude in a year, so it requires 25,868 years for the earth to complete the revolution of its wabble about its axis, as is indicated by the precession of the equinoxes. If this wabble is produced by the bulging outward of the earth at the equator, as is supposed, that bulging amounting to thirteen miles on every side, and it takes that long to complete the wabble, it would be sheer nonsense to claim that enough ice could be piled up in the polar regions to cause the earth to wabble every six months, or complete the revolution of a wabble once in a year, as would be necessary to produce a Glacial Period in a temperate zone.

It is not reasonable that ice could be piled up at the poles higher than the matter is piled up in the equatorial protuberance, which is about thirteen miles, because vapor to make snow will not ascend indefinitely. A limit will soon be reached beyond which height ice can not form, and then this accumulation will cease. It is probable the earth would have been an exact sphere had not its centrifugal force depressed it at the poles and piled it up at the equator. Then, if in the beginning this force was great enough

to send thirteen miles of matter toward the equator, and make the equatorial protuberance, is it reasonable to suppose that after this force has been fairly dominant for countless ages it would finally yield and become subservient to the same amount of matter which it had originally displaced? If the centrifugal force of the earth's rotations, in the beginning, sent thirteen miles of matter toward the equator, the same cause would produce like results at this late day. It would not produce a wabble every six months as would be necessary to produce a Glacial Period.

Croll's theory, to account for the climate of the Glacial Period, involves a change in the earth's orbit, in that it was at one time more elliptic than at present. A change in the orbit of the earth would produce an arctic climate all over the earth, if the change were great enough, but a change such as Croll supposed would hardly be sufficient. If we could enlarge the earth's orbit, — double the distance to the sun, — the effect would be a chilling of the earth and a frigid climate; but I have doubts that such would result from an elongation of the earth's present orbit, leaving the mean distance to the sun the same, for whatever heat would be lost to the earth while in the outside of this ellipse would be made up to it while on the inside, or at the point nearest the sun. The yearly aggregate of heat received would be the same. If those who believe that the Glacial Period was caused by a change of the direction of the axis while the earth's orbit remained the same, have correctly

stated their case, it is evident that such a change would not produce the effect claimed for it; but if they have not properly stated their meaning,—if they mean by it that the earth has changed its position in reference to its stationary axis, the axis remaining unchanged, — then they are not so much out of the way after all. In a future chapter it will be shown that the earth has a stationary axis, or one not subject to the theoretical wabbling as described above.

CHAPTER X.

THE STABILITY OF THE EARTH'S AXIS.

By the law of inertia, when matter free to move is given a revolving impetus, it has a tendency to arrange itself around a common axis, passing through the center of mass at right angles to the direction of motion. When this axis is once established, matter possesses no inherent power to change it. If no extraneous influence is brought to bear upon it, it will revolve on forever upon the same axis.

Now, suppose at the beginning of the career of our earth, when the motion of its diurnal rotation was once established, unless some outside influence should be brought to bear upon it to change or to complicate it, it would continue on forever upon the same axis.

Suppose the impetus which projected the earth in its orbit, and also started the diurnal revolution, was given in such a way as to incline the axis of its diurnal rotation sixty-six and one-half degrees to the line of the forward movement (the plane of the ecliptic), the law of inertia, as above stated, will require that this inclination continue forever, unless some external force is brought to bear to change it. All the matter composing the earth will revolve around this diurnal axis, and every particle completes the rotation in exactly the same time. To do this requires that

matter situated most distant from this central axis, and having a larger circle in its revolution, should move more swiftly than that close to the axis. Thus it is that matter at the earth's equator has a more rapid motion than that near the poles, but each completes its revolution in the same length of time, the difference in speed being due solely to the distance covered in making the revolution.

When the revolution of the earth around this central axis became fairly established, the centrifugal force of that motion caused, and still maintains, a swelling outward or bulging of the earth toward the equator, and a slight flattening at the poles. Theoretically, had the earth no diurnal revolution it would be in shape an exact sphere. The bulging outward

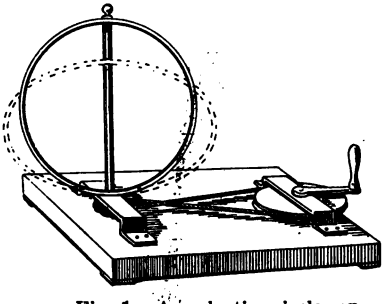

Fig. 1. An elastic circle or hoop fastened at the lower side of a vertical shaft, while the upper side is free to move. Impart a rapid motion by turning the crank and the hoop will be observed to bulge out in the middle and to become flattened at the ends.

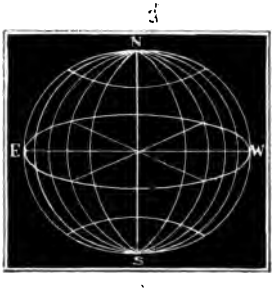

Fig. 2 represents the earth. It is supposed to have assumed this flattened form at the poles and bulged at the equator while it was yet in a plastic state.

toward the equator of a rotating globe in a plastic state will be in exact proportion to the rapidity of motion. If the motion is swift, it will be greater, and *vice versa.* With the earth it has been found that the bulging at the equator amounts to thirteen miles, with a like flattening at the poles, making the earth's equatorial diameter twenty-six miles greater than its polar diameter (the axis).*

It is supposed that the rotary motion of the earth produced the bulging at the equator while the whole mass was in a plastic state; since then the surface, with the exception of the water covering of the ocean, has become solid, still retaining its original shape — that of an oblate spheroid. This bulging toward the equator is called the equatorial protuberance. It is believed that this protuberance serves a very useful purpose. The great bulk of it being solid, acts as ballast and steadies the earth in its revolutions, preventing wabbling, etc. It would be the main obstacle to prevent tipping of the earth, were it loaded with ice in either hemisphere sufficient to materially alter its shape. Were this protuberance all water, it would not be so steady a ballast as it now is.

If we were experimenting with a rotating globe in a plastic state, and we wanted more piling up or

* It is said the Mississippi River in its course runs up hill about two miles—*i. e.*, the mouth is two miles farther from the center of the earth than its source. Were the earth's rotations to cease, the water in the Mississippi channel would run northward.

bulging at the equator, we must have increased motion. If we want less piling up, we must have retarded motion; but neither the one nor the other has any tendency to change the central axis. That remains stationary, it not being affected by the rapidity nor the slowness of the motion, nor by the smallness nor the greatness of the mass, nor by its density, if all particles composing it partake of the same general revolution and complete it in the same length of time. In our experiments with a globe, the resistance of the atmosphere, the attraction of the earth and the friction at the axles may be considered outside influences; but the earth is a globe, free to move, with none of these influences retarding it. The motion of the gigantic mass has a tendency to perpetuate the original axis. If from any natural causes matter on the surface of the earth is changed in position in sufficient quantity to materially alter the shape of the earth, the tendency is to restore the original shape again. Water free to move would gravitate to the place from whence the matter had been taken, and thus the equilibrium would be restored. Solid matter piled up in sufficient quantity to change the center of gravity will either fracture the crust of the earth by a crushing together of the matter beneath the pile, and swelling out of matter at other places, thereby restoring the original shape of the earth; or, if partially free to move, like ice on land, will be caused to move by the centrifugal force of the earth's rotations from the poles toward the

equator. Matter accumulated at the poles will either gravitate toward the equator, or it will displace other matter freer to move than itself, which will go toward the equator, and thus the equilibrium will be preserved. The erosion of water upon land surface has the same tendency. The particles of sediment are carried by the water and deposited where the center of gravity attracts them, and thus all things work together to preserve the original shape of the earth. The only way we can materially change the original shape — that of an oblate spheroid — is to change the motion, for the oblateness of the earth depends solely upon its motion; but none of the changes upon the earth's surface above mentioned have any tendency to change the earth's axis, which is the center of its rotary motion. The matter piled up has the same motion as the rest of the earth; has the same tendency to complete its revolution in the same time as any other matter on the surface completes its revolution, and hence must have the same axis. Matter of the earth possesses no power within itself to change its motion, and hence has no power to change the axis of that motion. Theoretically, if we want to change the axis of the motion, we will have to bring in some extraneous influence. If some cosmic matter, having a different motion from the earth, should strike it, it would have an effect upon its motions. The earth would have to bear the shock of checking or stopping the foreign body, and would also have to give up some of the power of its own motion to the

foreign body — divide with it, as it were — so that its particles, when united with the earth, would have the same motion as the rest of the matter composing the earth. The result would be a change in the motions of the earth, and also of its axis, unless the direction of the impetus was exactly toward the center of gravity. In that case the orbit of the earth would be changed, but the axis would remain the same; *i. e.*, would continue the same inclination to the plane of the ecliptic — would continue to point toward the North Star. If the impetus was received in a different direction than toward the center of gravity, or if the size of the foreign body was sufficient to materially change the shape of the earth, the result would be a changed and vibratory motion of the earth's axis, which would continue until the forces of nature have restored the equilibrium of shape and motion in the whole mass, when the earth will settle down to a permanent and regular revolution upon a changed axis; the new one, when fairly established, will be as fixed as was the old, but it will point in a different direction. The above is the only way, practical or theoretical, that would make a change of direction of the earth's axis.*

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* An experiment illustrating the above can be performed with an ordinary top. Bore a hole in one side above the center of gravity and fill it with lead, and in this condition spin it. The result will be a wabbling motion around the perpendicular axis, but the wabbling is as much on one side of the axis of motion as on the other. In fact, the original

A number of writers have claimed a change of the earth's axis during the Glacial Period (see Chapter VIII.), but I believe they either have an erroneous idea of the subject or else do not state exactly their meaning. They speak of the tipping of the earth as if it were balanced in the plane of the ecliptic — as if the latter were a solid and stationary substance, and the earth fastened to it on a pivot, so that by overloading the earth on either side of the pivot it would cause it to topple over. Now, this idea is erroneous. The earth has no pivot to tip upon. Its axis is but the center of its rotary motion in its diurnal revolution. This is all that holds the earth pointed toward the North Star.

Now, suppose we call this imaginary line, axis or center of motion the *pivot*. *The very idea of the tipping of the earth would carry with it the idea that the axis or pivot remained stationary.* There could be no tipping of anything without a stationary point between the tipping ends, and this stationary point is called the axis of motion, and, as a corollary to this, if the motion of the mass continue the same, the axis of the motion will continue the same. It can not be otherwise.

The gyroscope top furnishes a good illustration of the difficulty in changing the axis of motion in

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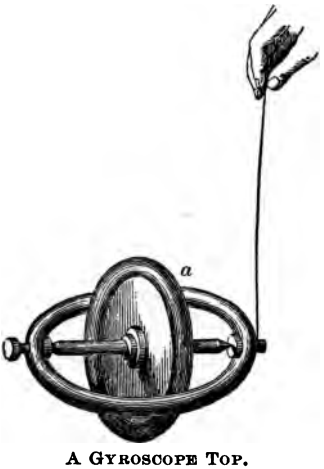
axis remains stationary, and the wabbling, as well as the rotations, is around this axis. Were it possible for the top to ever right itself and cease wabbling, it would be upon a perpendicular axis, which would be the original.

matter when once it is fairly started. Let those who believe that an ice cap around the poles will change the earth's axis take a gyroscope top and observe it and study it closely. Such a top, when in high motion, resists the gravity of the earth for a time, and continues to revolve on the same axis until the motion is diminished, when the gravity of the earth overcomes it and causes it to drop. Here the attraction of the earth, the resistance of the atmosphere and the friction at the axles act as outside influences and destroy the motion, when the axis will change and the wheel will finally drop, overcome by the earth's attraction. The same principle is well illustrated by a rotating bicycle wheel suspended at one end of the axle, as shown in the illustration, page 69.



A GYROSCOPE TOP.

In the case of the earth's motion, we are supposing it to be a gyroscope, working with none of the impediments which affect an ordinary gyroscope. It is plain that no change of position of any matter composing the earth can change or alter the direction of its axis, because the motion of the earth regulates the shape and position of the matter composing the mass.

A GYROSCOPE FROM A BICYCLE WHEEL.

Illustrates the stability of the earth's axis. Suspend an ordinary bicycle wheel at one end of the axle, as in the picture. Give it a revolving impetus and it will remain perpendicular until the revolutions become slow, when it will gradually tip over. It makes revolution also in an orbit in direction opposite to that in which the top of the wheel is turning. The periphery of this wheel represents the equatorial protuberance on the earth.

However impossible it may be for the matter of the earth to so change its position as to cause a change in the direction of the earth's axis to the ecliptic, yet it is possible — yea, even probable — that the matter composing the earth may change its position in reference to this stationary axis — may move back and forth past it as it is hurled by the centrifugal force of the earth's rotations, until finally

an equilibrium of the mass on the original axis is restored. If the earth were loaded with an ice cap on one side of the pole, of sufficient size to materially alter its shape, the influence of the centrifugal force would be to tear it loose and start it to moving toward the equator; or, if resistance was great enough, and the load large enough, it might cause the side of the earth containing the load to tip toward the equator — tip on another axis, passing through the earth from one side of the equator to the other at right angles with the original diurnal axis. The impetus that would cause this tipping would still be the earth's diurnal rotation; it would only be matter adjusting itself to the original axis, which will remain unchanged. While the motions of this tipping are going on in the earth, the axis of this motion is as stationary at right angles to the original axis as the original axis is stationary toward the North Star. But no matter can move past the axis of a balanced sphere at one end without a corresponding adjustment of matter at the other end and on the opposite side. The pivotal point being an imaginary line through the center of mass at right angles to the diurnal axis, all of which shows the stability of the original axis and the tendency of matter to adjust itself to this axis.

In another chapter I shall endeavor to show that just such an adjustment of matter to the original axis of the earth occurred near the close of the so-called Glacial Period.

CHAPTER XI.

TIME AND CLIMATE.

Prof. Le Conte has estimated the time since the sedimentary rocks began to be deposited on the earth to be thirty millions of years. (Geol., p. 276.) This estimate is from calculations made upon the amount of sediment carried annually by the Mississippi River.* "But," he says, "even this gives no adequate conception of the time involved in the geological history of the earth, for the same materials have been worked over and over again, perhaps, many times. Thus, the history of the earth *recorded* in stratified rocks stretches out in apparently endless vista. And still beyond this is the infinite unknown abyss of the *unrecorded.* The domain of geology is nothing less than (to us) inconceivable or infinite

* The estimate is as follows: Careful tests were made of the water as to the amount of sediment it contained, and from this calculations were made as to the whole amount carried by the river in a year. It was found to be a mass sufficient to cover an area of one square mile 268 feet deep. This sediment all came from the Mississippi basin, which contains 1,244,000 square miles, and if spread over the whole basin would cover it 1-4640 of a foot deep. Therefore this river removes from its basin a thickness of one foot in 4,640 years. Then estimate the thickness of the sedimentary rocks of the earth at 6,000 feet. To make them at the rate of Mississippi sedimentation would take about thirty millions of years. (Le Conte's Geology, p. 11.)

time." (*Ibid.*, p. 278.) Prof. Gray's estimate upon the age of the earth is 52,800,000 years. Prof. Dana concedes the general proposition that *time is long.* His figures on the age of the earth are as follows: "Paleozoic time, 36,000,000; Mesozoic, 9,000,000; Cenozoic, 3,000,000; in all, 48,000,000 of years since the commencement of the Silurian Period." This time has elapsed since the introduction of life upon this earth, and he says: "The time of the earth's beginnings before the introduction of life must have exceeded in length all subsequent time." (Dana Geol., p. 375.) This would put the probable age of the earth at about 100,000,000 of years. Other geologists have come to similar conclusions. Sir William Thompson (Lord Kelvin) has, from calculation made upon the conductivity of heat, fixed the age of the earth to be somewhere between 20,000,000 and 100,000,000 of years. More recently, in discussing the subject, he inclines to the opinion that the later figures are more nearly correct. (Enc. Brit.) His idea is, if heat had always been conducted out of the earth at its present rate, it would have required 20,000,000 or 30,000,000 of years to have cooled the earth from a molten to its present state, and if the earth had been cooling 400,000,000 of years, there would now be no sensible increase of heat downward in the earth's crust.

H. H. Hutchinson's figures on the age of the earth are 600,000,000 of years. McGee, including in his basis the rate of denudation at Niagara, and giv-

ing credit to the extreme estimates of thickness of the early paleozoic formation, estimates the age of the earth to be 6,000,000,000 of years. (Dana — Manual, p. 1,025.)

However much these calculations may differ in minute results, they all agree in one thing, and that is that this terrestrial sphere has been here a long time. As no one who has examined the evidence seems inclined to dispute the proposition, we may accept it as a settled fact that this earth of ours is *very old.*

Now, with an idea of the antiquity of the earth in our minds, we look backward at the evidence to see what kind of a climate it has had in the past. In this matter, too, geologists are pretty well agreed that down to the close of the Tertiary Period the prevailing climate all over the earth was tropical or semi-tropical, and there were no ice caps at the poles. They have arrived at this conclusion from the character of the fossils, both animal and vegetable, that have been deposited in the strata of the different geological periods. Prof. Le Conte, after describing the immense number of species of ferns which grew in the Coal Period, says that "To-day four-fifths of this family, together with arborescent Lycopods, Cycads and Araucarian Conifers, are wholly confined to tropical or sub-tropical regions. The presence of these tropical families and their immense size would seem to indicate not only tropical but *ultra*-tropical conditions. These conditions prevailed not only in the United States and Europe, but northward into polar regions;

for *in Mellville Island, 75° north latitude, and Spitzbergen, 77° 33′ north latitude, have been found coal strata containing tree ferns, gigantic Lycopods, Calamites, etc.*" Prof. Dana says: "Corals and shells not only existed during the Sub-Carboniferous Period in Europe and the United States, but in the Arctic regions within 20° of the north pole, and so profusely as to form thick limestones out of their accumulations. The ocean waters, even in the far north, were probably quite as warm as the coral reef seas of the present age which lie mostly between the parallels of 28° on either side of the equator." Other testimony could be given showing that the earth during Paleozoic time was possessed of a tropical climate even in the far north; but I believe the point is generally admitted by geologists, and hence further testimony is unnecessary. For this warmth to have existed in the far north at that time, it is evident there could have been no ice caps at the poles. The same may be said of Mesozoic time. I find the following in Le Conte's Geology under general observations on the Mesozoic: "The climate was then uniform and warm, as is sufficiently attested by the character of fauna and flora. The tropical fauna and flora were substantially similar in all latitudes in which the strata have been found, even as far north as Spitzbergen." We now come to Cenozoic time. Prof. Newberry says (Geol. Sur. Ohio, Vol. XI., p. 65): "From the Tertiary deposits of the far north — Alaska, Green-

land, Spitzbergen, etc. — the remains of more than two hundred species of plants have been procured, which show that all the Arctic land then enjoyed a mild climate." The fact is, the fossils of the Tertiary Period are substantially similar in all latitudes, whether polar or tropical, where the Tertiary formation has been found. This is true not only in reference to this period, but of all other geological periods prior to the Glacial Period. Prof. Le Conte says: "All the evidence derived from fossils plainly indicates warm climates even in polar regions, during all geological periods until the Quaternary." (Geol., p. 592.) That the polar regions were warm during the Tertiary Period is also attested by the remains of animals, including the mammoth, mastodon and other tropical species that have been found far in the north. Thus we have abundance of evidence that the climate of the earth was warm, even into the polar regions, down to near the close of the Tertiary Period.* Then

* If there were other periods in the past when the earth was overcome with arctic chill, exterminating the fauna and making the transition from one period to another, as some geologists have supposed, it is reasonable to conclude that such chill had its origin in the same causes that produced the last Glacial Period. We are seeking to unravel this one, and if we can find out the cause of it, then we have a key to the others, if such existed. It does not militate against our theory of the cause of this even to admit there might have been other glacial periods before this one, and if our theory is correct, there will be times in the future when the Arctic ice sheet will be extended into the temperate zones and these zones again ground by glaciers.

all this was changed. A chill came over the earth, and the Glacial Period was ushered in. How long the so-called Glacial Period continued, scientists have not been able to determine, but, judging from the effects produced (the amount of erosion — the valleys filled and hills leveled), and then considering the length of time it would have taken for sufficient ice to form from the annual snowfall to do all this, we come to the conclusion it must have lasted at least some thousands of years. When we consider the thickness of the ice in the polar regions at the present time, which is in many places from two to six thousand feet, and even ten thousand feet, thick on the Antarctic Continent (Enc. Brit), and the length of time it would take for such ice to form; when we think of the length of time it would take for the soil at Yakutsk, in Siberia, to freeze to the depth of seven hundred feet, which has been found to be the present condition (Enc. Brit.); when we consider that, in all probability, the polar ice caps were far advanced before this soil began to freeze or to carry the frost over the summers; and when we find the remains of preglacial animals imprisoned in the ice of Northern Siberia, we come to the conclusion that this ice has existed from near the time that these animals roamed over the earth. Their disappearance was about contemporaneous with the commencement of the Glacial Period in North America; so that this ice has existed

from near that period.* What made the change of climate at the commencement of the Glacial Period has been a puzzle to scientists ever since the effects of glacial action began to be observed, and they have not yet come together upon any common explanation that is satisfactory to all.

The essential points in this chapter may be summarized as follows: First: The earth is very old. Second: It has always had a tropical or semi-tropical climate, down to near the close of the Tertiary Period, and there were no ice caps at the poles. Third: At the end of the Tertiary Period the climate was changed. Fourth: Ice caps have existed at the poles ever since the Glacial Period.

An explanation of the cause which brought about this change of climate will be reserved for another chapter.

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* The length of time since the Glacial Period has been estimated from the gorge below Niagara, which it is reasonably assumed has been cut by the river since that period. The present annual advance of the falls has been variously estimated at from three feet a century to one foot a year. By the latter, to have made the six miles of gorge would have required thirty-one thousand years. By the former it would have taken three hundred and eighty thousand years. These estimates agree in one thing at least, and that is, that *time is long.* (Dana's Geol., p. 376.) By Croll's theory it has been eighty thousand years since the Glacial Period began to decline.

CHAPTER XII.

WHAT CAUSED THE CHANGE OF CLIMATE.

As we have shown in the last chapter, the earth had been possessed of a warm climate throughout all its existence previous to the Glacial Period, and at this time a changed condition came over it. What made that change? Was any new law introduced to govern the phenomena of this earth? I think not. It was the result of the same natural laws which had always been in existence, and to which the earth had always been subservient. The change came about in this way:

According to the nebular hypothesis, the earth at one time existed in a gaseous state. That was a long time ago. It is believed by the advocates of the nebular theory that heat reigned triumphant, so that none of the elements of the earth could exist in a solid or liquid form, but it, like every other heated substance, was destined to cool off. This great heat was bound to be dissipated into space, according to the law which governs the radiation of heat. So it was with the former heat of this earth. The cooling began and progressed until the matter of the earth reached a liquid state, but the process was not destined to stop here. The cooling must go on. At last a point was reached in the cooling process when a crust of rock began to form on this liquid mass. No doubt

the first portions of such a crust would form for a time and then sink into the fiery liquid beneath, there to be remelted, and this process went on for a geological age; but at last the earth had given up sufficient of its heat — had cooled off to the extent that a solid crust of rock was formed all over the surface of our globe. At this time all the water of the earth existed as steam or gas in the atmosphere. A cloud surrounded the earth so dense that all sunlight was excluded; but the cooling went on. This vapor in the atmosphere became condensed into water and sent down showers of rain such as never had been nor ever will be again. A "cloudburst" is nothing to be compared with it, and the rain was general all over the earth and continued for an age. This water would fall upon the heated rock crust, to immediately be dissipated and sent up again as steam; and so the process went on. But at last the water gained the ascendency and so far quenched the fire and dissipated the heat that it became possible for water to exist as a liquid on the surface of the earth, and then the ocean had entire sway. All the rock crust of the globe was covered by an ocean of boiling water, but the cooling process went on. When the rock crust became sufficiently thick to sustain itself as an arch, *vacui* would sometimes occur beneath it. The weight above would fracture these arches, allowing the crust to crumple, fold and settle down to rest upon the molten matter beneath. In this way troughs were formed, to become the beds of oceans, while

upward folds were crowded above the water, to become dry land and mountains. This process went on during all the geological ages, but from the continual cooling the crust was getting thicker all the time. The breaks became less frequent as time went on, but when they did occur the phenomena attending them were more pronounced.

Now, there is nothing new in the above. I have in my own way been presenting the nebular hypothesis so far as it pertains to this earth — a theory which is taught in all the colleges and pretty generally accepted by scientists all over the world.

If scientists can believe the nebular hypothesis; if they can believe that the earth in the beginning was extremely heated, and has ever since been cooling off, it seems to me strange that they have so much trouble to account for a Glacial Period. Why do they not continue the same process of reasoning until they get to such a period?

The answer will be that the chilling of the Glacial Period came on too suddenly to be accounted for in that way; and, besides, the climate has moderated since then and the ice has disappeared, proving conclusively that the cold of the Glacial Period did not originate from the gradual cooling of the earth. Prof. Wright says: "If the Glacial Period was due to the decrease of the original heat of the planet, the period should not have culminated in the past, but we should still be looking for the culmination in the future; for both the earth and the sun are cooling off.

We may, therefore, drop out this theory." (Ice Age, p. 407.) The author does not intend to drop this subject quite so readily, but will examine it further.

In our reasoning we will try to keep upon admitted ground, at least until we come to the very verge of the Glacial Period, and then if we, by the same process of reasoning as has been admitted previously, succeed in crossing the chasm that divides the Glacial Period from previous geological ages, I see nothing to prevent others who believe in the nebular hypothesis from venturing upon the same bridge.

It is pretty generally conceded by scientists that the earth from the beginning has been going through a cooling process which is not yet complete. During all geological time the ocean has been the great distributer of heat over the surface of the earth. This, too, is generally admitted. The tropical portions of the ocean receiving more of the sun's heat than the polar regions, would cause oceanic currents, which would carry this excess of heat and distribute it toward the poles, and thus the surface heat of the earth would in a measure be equalized, and thus no ice caps could form at the poles as long as these ocean currents had uninterrupted sway. So far are we not on safe ground?

Another fact universally admitted by geologists is that toward the close of the Tertiary Period was the great mountain-building era of the world. Nearly all the great mountain chains of the world were either built up or very much elevated in height at that time.

"This was one of the great mountain-building epochs." (Dana.) "At the end of the Miocene occurred the greatest event of the Tertiary Period, and one of the greatest in the history of the American Continent. The sea bottom of the Pacific Coast was crushed together in the most complicated folds and swollen up into the Coast chain. Coincident the Sierra and the Wasatch assumed their present form and height. The *down sinking* of mid-Pacific bottom and bodily upheaval of the Pacific side of the continent are closely connected with each other." (Le Conte.) The coral islands nearly all over the Pacific are monumental records of the subsidence which the bottom of that ocean has undergone. Reefs form only in shallow water. To continue the formation of a reef, there must be continual subsidence. The area of the subsidence in the Pacific Ocean is given as six thousand miles in length and twenty-five hundred in width. (Dana — Manual, p. 392.) "The Rocky Mountains were raised as a whole during the Tertiary." The sea covered them during the Cretaceous. (Dana — Geol., p. 170.) Like changes took place with the Andes, Alps, Apennine, Carpathian,* and, in fact, in nearly all the great mountain chains of the world. I do not mean that they were all made at that time, but that many new ranges were made, and many of the older ones were heaved up or very much increased

* The Himalayas, although begun in the Tertiary, have been very much enlarged in a more recent period.

in height. So far as the evidence goes, this crumpling and settling of the earth's crust took place in the torrid and temperate zones, and there was no compensating change took place in the frigid zones.

As nearly all the great mountain chains of the world were heaved up about the same time, they were, no doubt, the result of *one* comprehensive cause. The amount of shortening of the earth's crust, as shown by the overlapping of strata of the Alps, is seventy-four miles (Heins), and that on the Pacific side of the American continent (being the crumpling of the Rocky Mountains and other ranges) is estimated by Prof. Dana to have been seventy-five miles. (Manual, p. 391.) Here is a shortening of the arch of the earth's crust of about one hundred and fifty miles made by two mountain systems alone. There are others which should be taken into calculation, but from lack of data will be omitted. A shortening of seventy-five miles on one side of one ocean, and from the way the strata are displaced, the pressure all came from the side toward the ocean. It was the bottom of the ocean which settled. There was no settling on the other side of the mountains. If any change, the land in the interior of the American Continent was raised; especially was this true in regard to the Great Plains lying eastward of the Rocky Mountains, and whatever elevation there might have been produced in the land of the interior would also work a shortening in the arch from whence the pressure came. Given an arch with a curve of the earth's sur-

face and the width of the Pacific Ocean, and take seventy-five miles out of it, how much will the arch settle?

Whatever it would be, would immediately be compensated on the surface by the water drained from other regions. Here we have a key to the mystery. Up to and during the principal part of the Tertiary Period the earth had so far cooled and the rocky crust had become so thickened that it sustained the pressure of the arch for a long time, but finally the point was reached when it could sustain it no longer. "The last grain of sand broke the camel's back." The arch gave way or crumpled into the form of mountains, and as the crust was thicker at this time than any time previous, so were the upheavals in the form of mountains greater than any which had preceded them, and of course the troughs formed from the settling of the arch would be greater; thus the beds of the oceans settled down, forming deeper basins, thereby draining the polar regions and leaving them above water (especially was this the case around the North Pole), depriving them of their warm ocean currents, or water covering, and allowing them to cool off and begin to form ice caps.* The warm climate of the Tertiary Period continued until the settling process had so far drained the polar

* Will any other hypothesis account for the fact that all the principal mountain chains and principal oceans of the world extend in a northerly and southerly direction? It looks as if they were especially designed to drain the polar regions.

regions as to allow ice to begin to form when the climate began to change, which change continued until the Tertiary merged into the Quaternary. Thus began the formation of ice which finally culminated in a Glacial Period. The conditions present were these: A land foundation around the poles for ice to rest upon. The circulation of the ocean shut off or confined to the regions south of the land barrier, but having free circulation with the tropical regions. The ocean thus confined would become warmer than it had previously been. If it had been carrying a certain amount of heat to be dissipated around the poles, and on account of the land barriers this heat were to be confined south of the polar regions, what would prevent the water from becoming warmer? Here we have a steaming ocean to furnish the vapor and a cold land surface to precipitate the snow, the conditions in perfection to produce a glacial period.

Now is there anything unreasonable in this? But you will ask, Why were the polar regions left above water? Because they were farther from the equator, more cooled off, and consequently the rocky crust under them was thicker and more able to bear the pressure which settled the other regions. Hence the arch there withstood the pressure, while the other regions fractured and settled down, or heaved up into mountains.

Thus we have the conditions to produce a glacial period; and have we introduced any new process? None at all. The whole thing was brought about by

a gradual cooling of the earth — the same which had been going on from the first, and is still going on.

The point to be remembered in this chapter is that the great mountain chains of the world were heaved up about the time the climate changed. I claim a connection between these two events.

CHAPTER XIII.

THE GLACIAL PERIOD.

In the last chapter I showed how the Glacial Period was ushered in, and in the present I will endeavor to show that it has existed ever since that time. We make a mistake when we speak of the Glacial Period as a time passed. It is not passed. When we speak of a past Glacial Period, we have reference to an epoch in the Glacial Period; but after that epoch the period still continues, and glaciation is still going on in the same manner and with the same results as those produced during any time in the past. The reason we do not see it at present is because we are outside the glacial zone. Had we been situated without the glacial zone while the drift in North America was being formed, we would have known no more about it than we do now. Extensive glacial action up to the present time is a phenomenon peculiar to the frigid zones. The explanation as to how the drift region came to be extended outside of the present frigid zone will be reserved for a future chapter. For the present I will affirm that the Glacial Period is still going on. The ice is rapidly accumulating in the polar regions and slowly creeping downwards toward the temperate zones. The Chicago *Evening Post* quotes the following from a leading

German meteorologist and astronomer: "Places visited by Kotzebue, Ross, Franklin, Parry and others during the first quarter of the present century, and pronounced by them to be free from ice during June, July and August, are now covered with several feet of solid ice, which is capped with snow throughout the year. This certainly proves that the earth's glacial zones are rapidly and permanently enlarging. Flammarion, the great French astronomer, has shown that every country in Europe, as well as those in Asia, has, during the last fifty years, lost from six to fourteen degrees in its mean annual temperature. In France, Germany and Italy the northern limit of the growth of the vine is steadily being pushed southward. In South America and South Africa similar conditions are noted. At Rio Janeiro the annual temperature has been steadily going down since the date when meteorological records were first kept in that city." I have before me a volume on the polar regions compiled from reliable sources. It, in speaking of the discovery and colonization of Greenland, about A. D. 982, by Eric the Red, says: "Having spent three years in exploring the coast, he returned to Iceland, where he promulgated such a glowing description of the new land that great numbers of his countrymen followed him thither the ensuing spring. No less than twenty-five ships sailed in his company. In course of years new colonists arrived from Iceland and Norway and settled so numerously on the east and west coasts that their numbers were computed to

be equal to the third part of the population of a Danish episcopal diocese." The same author, after describing the present desolate condition of Greenland, continues: "This, then, is the land that the early northern navigators described as a terrestrial paradise, and to which they gave the name of Greenland from its vegetation. Either the soil and climate must have undergone a total change, or they were but indifferent judges of arable land." The probabilities are that the climate has changed since then, for no one, under the present conditions, would think of naming such an inhospitable region, as that now is, Greenland.

Prof. Geike says: "I am aware that several Arctic explorers are of opinion that the climate of Greenland has altered for the worse within quite recent times. The huts of Esquimaux have been met with in places which are now not visited by the natives. And this, taken in connection with other evidence, points, as some think, to somewhat milder climate having prevailed in these regions within even historical times." (Geike's Ice Age, p. 464.) "But," he adds, "the succession of a few unusually mild years would possibly explain all the appearances referred to." It is not comforting to think that the ice sheet is advancing.*

* The fiords and indentations that occur along the coasts in the Arctic regions appear to be the remains of ancient valleys, which were eroded before the ice sheet was formed. The coast of the Antarctic continent does not seem to be thus indented. (See plates, pages 15 and 102.)

Prof. Wright says from recent reports it would seem that the glaciers of Iceland have for some time been rapidly advancing. (Ice Age of North America, p. 95.) The same condition seems to be present in Alaska. The same author describes and pictures a forest which had been covered by the ice of an advancing glacier, and afterward partly uncovered by a change in the direction of the moving ice. "The existence of other forests similarly preserved in that vicinity is amply witnessed to by many facts. . . . Our whole dependence for fuel during the month was upon such fragments lying exposed in the moraine. . . . As no forests were visible anywhere in that direction, it is presumable that they had been excavated from preglacial forests." (*Ibid.*, p. 62.)

Prof. Wright further states: "That many of the trunks of these trees are standing upright in the soil in which they grew, with the *humus* still about their roots." "The roots of these trees are in a compact, stiff clay stratum, blue in color, without grit." (*Ibid.*, p. 59.)

"The fact that stumps, etc., of full-grown trees have been found in places where at present nothing is met with but fields of snow and ice, and where the mean annual temperature scarcely rises above zero (Fahr.) is good evidence to show that the climate of the Arctic regions was once much warmer than now."

"The remains of an ancient forest were discovered by Captain McClure in Banks Land, latitude

74° 48′. He found a great accumulation of trees from the sea level to an elevation of upwards of three hundred feet. . . . From the perfect state of the bark, and the position of the trees so far from the sea, there can be but little doubt that they grew originally in the country." (Climate and Time, Croll, p. 261.)

The same author mentions a similar instance where a tree was discovered four feet in circumference, under the ice in the interior of Prince Patrick's Island, latitude 76° 12′, by Lieutenant Mecham.

Captain Parry also found similar trees on Melville Island. They have also been found in New Siberia. Captain Belcher found a tree standing erect near Wellington's Sound, latitude 75° 32′. It was one and one-half miles inland. It was dug out of the frozen soil with the dirt on its roots, packed in canvas and brought to England; thus proving conclusively that it grew where it stood.

If the above reports are true (and I have no reason to doubt their correctness), they certainly show that the ice sheet is advancing. They also have a direct bearing in opposition to Croll's theory. How will the advocates of that theory explain them? The earth has been getting colder while it has been approaching both its mid-winter perihelion, and also the least eccentricity of its orbit. The two do not harmonize. To sustain Croll's theory, the polar regions should have been getting warmer ever since

the colonization of Greenland by Eric the Red.* But whether the glacial zones are enlarging or not at the present time is not material to our argument. It is evident that they are not retreating, and were anything to interrupt the ocean currents, and prevent them from carrying warm water into the polar regions, they would enlarge rapidly. Baffin's Bay is six hundred miles wide and carries a polar current

ICEBERG.
From Wright's Ice Age, by courtesy.

* I suppose, according to Croll's theory, the warmth in the polar regions during the Tertiary Period would be accounted for by saying it occurred while the earth in winter was in perihelion, and while its orbit was the least eccentric. That condition has returned again, consequently those regions should now be enjoying a semi-tropical climate, but we find it right the opposite. Here is another place where Croll's theory does not fit the facts in the case.

down through it that flows from two to five miles an hour. This is a return current bringing back the water that was carried northward by the gulf stream. It bears with it icebergs loaded with drift (rocks and sediment), which usually break up along by Newfoundland and distribute the drift in that region. It is believed that the great sand banks east of Newfoundland were made in that way. The ocean has become so shallow from the deposit of this sediment that icebergs are frequently grounded upon these banks and held until disintegration is accomplished by the heat of the sun and the storms of the ocean. This process alone will finally block up the outlet of Baffin's Bay. That result is inevitable. Baffin's Bay is doomed to become an inland sea. Behring's Strait is not large enough to effect much in the transportation of icebergs or the distribution of polar currents, and it is also very shallow. With Baffin's Bay blocked, there will be no way left for the return of polar currents but for the gulf stream to double on itself in the Atlantic. This will be but a miserable makeshift that will finally allow the polar ocean to freeze to the bottom, and become a palæocrystic sea; then good-by to all tropical currents and every prospect of relief to the polar region from congestion of ice. With the polar ocean frozen to the bottom, and ice still accumulating on the surface by the continual precipitation of snow, glaciation will be set up in the whole mass. It will move on the bottom of the

ocean and crowd the water back, thus enlarging the ice field.*

It is easy to see that the process is at work that will finally extend the ice caps of the polar regions toward the south. This condition is destined to go on with increasing ratio in the future, with a constantly narrowing down of the inhabitable portions of the globe. With the ice now in Greenland from three thousand to six thousand feet thick, and on Antarctic Continent two miles in thickness; with the soil at Yakutsk, Siberia, frozen to the depth of seven hundred feet; with all the waters of the oceans below the depth of four hundred fathoms chilled to near the freezing point of fresh water, and in many places below that point — tell me not that the Glacial Period is over. Every chill wind that blows down from the north is a reminder that the glaciers are still with us and that the Ice Age is not past. But one to see glaciers will have to go where the glaciers are. If one happens to be situated without the glacial zone, and on that account claims that the Ice Age is past, he should either go to a place where he can see glaciers, or accept the testimony of others who have been there, that the glaciers are still with us and the Ice Age not past, but rather is on the increase.

Lest the reader misunderstand me, I will say that the phenomena usually attributed to a passed Glacial Period will receive attention in the next chapter.

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* Several explorers have observed places in the Arctic Ocean where it is supposed to be frozen to the bottom at present, and the ice still accumulating, forming sea glaciers.

CHAPTER XIV.

THE GLACIAL REGION AND THE PROBABLE THICKNESS OF ICE DURING THE MAXIMUM OF GLACIATION.

Some time in the remote past, historically speaking, or in the recent past, geologically speaking, a large portion of the northern hemisphere which is now clear of glaciers was covered with ice. The phenomena observed in reference to this are usually spoken of as due to the Glacial Period, but, correctly speaking, should be attributed to an *epoch* in the Glacial Period. These phenomena were produced during the present geological age of the earth, and the amelioration of the climate and the disappearance of the ice over this territory marked an epoch in the Glacial Period known as the Champlain Epoch, a description of which will be reserved for a future chapter.

The glacial region extends in a semicircle exactly half way around the globe. The moraine, as given by standard authorities, begins in Europe at the shore of the Arctic Ocean, near the Ural Mountains, longitude fifty degrees east. It extends southwestward across Russia and Germany, meeting the Atlantic near the outlet of the English Channel. The trend of this line is southwest, but it is in the main a curve, being nearly the arc of a circle. On the west side of

MAP OF GLACIAL ICE SHEET.

Dotted line (- - - -) indicates boundary of Ice Sheets during the maximum of Glaciation.

the Atlantic it emerges on land near the city of New York (latitude 41°); then takes a westerly course across Pennsylvania, Ohio, Indiana, Illinois (37° 30′); crosses the Mississippi near St. Louis; follows near the Missouri River across Missouri; then through Kansas, Nebraska, Dakota, Montana, crossing the Rocky Mountains near the boundary of the United States and British America; then northwest through British Columbia and Central Alaska, reaching the Arctic Ocean at longitude 130° west, extending in all 180°, or one-half way around the globe. This line makes the same curve in America as in Europe. Its most southern extension is in Southern Illinois (37° 30′). All the territory north of this moraine, as far as examined, shows evidence of glacial action. South of it none is observed. Here is where the ice sheet terminated.

If we imagine this line to have followed near a parallel of latitude during the period of maximum glaciation, we get a correct idea of the glacial field. The pole of this circle is somewhere near the center of Greenland,* and had the distance from this point

* It will be observed that the center of the ice field, as approximately located in the above description, is far to one side of the present pole. If during the Glacial Period, this point was near the pole, then meridians drawn from it, covering the glaciated area, would include more than one-half the circumference of the earth, but that is immaterial to my argument. What I desire to impress is, that *there was no glaciation over Northern Asia.* That admitted, I shall not contend for the exact boundary lines of the glaciated area.

to open water been equal all around the earth, it would have been the center of the ice field.

Various estimates have been made as to the depth of the ice over this territory during the period of maximum glaciation. The probabilities are that it was thickest near the center of the ice field, gradually thinning out toward the borders; and yet we have direct evidence that the borders were of enormous thickness.

There are three methods of estimating the probable thickness. First: There is the direct evidence furnished by the height of glacial marks on the sides and summits of mountains. Secondly: The transported bowlders which have been traced to their sources. Calculations have been made from the distance traveled by them. Thirdly: Calculation can be made from the size of the glaciated field and the slope that would be necessary to give motion to the ice. By the first method it is found that the ice sheet in New England came near the top of Mt. Washington, for Prof. Hitchcock found transported bowlders within three or four hundred feet of the summit. It passed over the Green Mountains in Vermont, where they are from three to five thousand feet high. Prof. Agassiz claimed that a glacier would not pass over a mountain unless its thickness on top of the mountain was at least one-half the height of the mountain. Prof. Dana estimates that the height of the ice above the region of New Haven, in Connecticut, may have exceeded two thousand feet, and could not have been

less than fifteen hundred. It will be recollected that the points above mentioned are well toward the southern border of the ice sheet. Prof. Newberry, in speaking of the erosion on Kitatinny Mountain, near Delaware Water Gap, said: "If there was that amount of erosion there, what must it have been further north, where the ice was *ten times as thick and continued to act ten times as long.*"

The divide between the Great Lakes and the Ohio River is from five to six hundred feet above the lakes. The ice pushed over this divide and reached and crossed the Ohio River at Cincinnati, and, as Prof. Wright thinks, dammed the river to the height of five hundred feet. Think of the enormous mass of ice there must have been behind this to have forced it across the depression of the lakes and over this divide!

Bowlders have been traced from the Lake Superior region to the flanks of the Rocky Mountains, and left at an elevation of four thousand feet. (Dawson.) These must have traveled at least seven hundred miles. A moderate inclination of one degree to the surface of the ice, like the glaciers of Greenland, and this continued that distance, would give a thickness of nearly twelve miles at the center. If we say it was but one-half a degree, or forty-five feet, to the mile, like that on Antarctic Continent, it would give us a thickness of about six miles. Many of the bowlders in Southern Ohio are supposed to have come six hundred miles. It is found in tracing bowl-

ders that the farther we get from their source, the smaller they become. In other words, the bowlders wear out by the continued attrition. It is therefore doubtful if bowlders can be traced more than six or seven hundred miles. Hence we could not expect to find bowlders near the southern border of the ice sheet which had traveled all the way from the center, and the absence of such is not conclusive evidence that the ice did not come so far.

Prof. Dana has estimated that the ice over the divide between the waters of the St. Lawrence and those of Hudson Bay must have been at least two miles in thickness. Prof. Wright estimates that four million square miles in North America and two millions in Northwestern Europe were once covered with ice a mile or more in depth. (*McClure's Magazine*, p. 134, June, 1901.)

It seems incredible that ice should accumulate several miles in thickness; hence it appears to me that those who have estimated the thickness of the North American ice sheet during the maximum of glaciation have rather been inclined to underestimate than to overestimate it. It seems to the writer that we would come nearer to the truth if we follow the method of Prof. Croll, who calculates the ice in the center of the Antarctic Continent to be twelve miles in thickness. His method is as follows: The continent is estimated to be twenty-eight hundred miles in diameter, hence fourteen hundred miles to the center.

The ice is moving seaward on every side that has been explored. The slope of the surface of the ice is estimated to be one-half a degree, or forty-five feet, to the mile. This continued, fourteen hundred miles will give a thickness of twelve miles at the center. This thickness at first glance seems incredible, and yet, when we come to compare this thickness with the broad area covered, it is but little more in proportion to width than the carpet in an ordinary room. It is like the water of the ocean, which we ordinarily consider deep, yet, when we compare the depth with the area, it is similar to a basin of water one hundred yards square and one inch deep, which gives the impression as being very shallow indeed.

The Antarctic ice sheet undoubtedly thins out toward the border; but from the size of the icebergs which have been observed in the Southern Ocean, and which are supposed to have been detached from the border, it still must be of enormous thickness. Some of the icebergs in the Southern Ocean definitely reported were in height 500 feet, 580 feet, 600 feet, 700 feet, 800 feet, 960 feet, and 1,000 feet. Since the density of ice to that of sea water is as 1 to 1.115, every foot above water indicates 8.7 below the water, the largest of the bergs must have been a mile and three-quarters in thickness. Of course, some allowance must be made for the possible fact that the base of these icebergs may have been much broader than the top; but, even allowing for this, some of them

ANTARCTIC ICE SHEET AS OBSERVED BY SIR J. C. ROSS.

From Geikie's Great Ice Age.

must have been a mile in thickness; and, as icebergs do not form in open ocean, it is evident that for such ones to exist there must be somewhere on land ice of equal thickness from which they were detached. Therefore the estimates of Prof. Croll upon the thickness of the ice in the center of the Antarctic Continent seem not to be unreasonable.

FLOATING BERG, SHOWING AMOUNT SUBMERGED.
From Wright's Ice Age, by courtesy.

Now, if we apply Croll's method of estimation to the ice sheet that once covered North America, what do we get? The distance from the center of Greenland (which appears to have been the center of the ice field) to the southern border of the ice sheet, as marked in Ohio, Indiana and Illinois, is about twenty-

five hundred miles. A slope of one-half degree, or forty-five feet, to the mile carried this distance will give the thickness of about twenty-one miles, which, were there no other factors complicating the question, would be the probable thickness of the ice at the center during the maximum period of glaciation in North America.

It is said that granitic bowlders of foreign origin have been found over Iceland (L. T. Townsend, in Credo, p. 106), and if this report is true, it would seem to indicate that the ice sheet of Greenland pushed across the East Greenland channel and over Iceland. Were such an ice sheet now advancing into the ocean, it would be sufficient to recover the greater part of the bottom of the North Atlantic, for nowhere between Scotland and Iceland is the water more than six thousand feet deep, and mostly but six hundred. (Dana.) It is evident that such depressions as Baffin's and Hudson Bays would be no impediment to the advance of such a glacier; but allowance must be made for the probable fact that the depression of the Atlantic would probably cause the ice to move in that direction, thereby diverting it from the other course. Therefore, it is doubtful if the accumulations in the center ever reached the extent to cause the ice to move from that point towards the southern border of the field (as marked in Ohio, Indiana and Illinois). But, after making due allowance for all possibilities of error, it seems

not to be unreasonable to conclude that the mean or average thickness of the ice sheet which glaciated North America was as thick or thicker than that now covering the Antarctic Continent, which is usually estimated at two miles in thickness.

CHAPTER XV.

THE CHAMPLAIN EPOCH.

At the close of the Tertiary Period, when the ice caps began to pile up around the poles, as has already been explained (see Chapter XII.), — after this piling up had advanced to a certain extent, glaciation commenced. The whole mass began to move slowly in the direction of the least resistance, which in the main was in a southerly direction, as is shown by the striæ. The cause of this motion in the ice has been the subject of much controversy among scientists. The fact is admitted by all that ice in sufficient quantity will move in the direction of least resistance, but the cause of such motion is not well understood. I have not space to enter into a discussion of the different theories to account for the motion of glaciers, and such discussion is not necessary, since almost any text-book on geology or physics will give them.

I will only call attention to a cause, not usually mentioned in text-books, which played an important part in moving the ice during the Glacial Period.

When the fracture of the earth's crust that raised the great mountain chains of the world occurred; when the troughs of the oceans settled down, thereby draining the polar regions (see Chapter XII.), these were left as elevations, the same as any other elevated

plateaus. If the earth were solid, and in shape an exact sphere of its present size, and you cover this sphere with an amount of water equal to that at present in the oceans, what would be the result? The centrifugal force of the earth's diurnal rotations would send this water to the equatorial regions thirteen miles deep, and the poles would be left thirteen miles out of water. Here we have thirteen miles of an eminence, amply sufficient to produce almost any degree of cold, and also a slope extending several hundred miles, sufficient to account for the motion of the ice in a southerly direction. Here is where the northern elevation, which nearly all geologists say must have accompanied the Glacial Period, comes in. The great wonder is that they have not seen what caused it.

Thus it will be seen that we do not antagonize those theories which have supposed a northern elevation existed at the time of the Glacial Period; but, on the contrary, the above explanation of the cause renders them intelligible and plausible.

Or, suppose the northern elevation was not so great as above described — even not great enough to furnish an incline sufficient to cause a movement of the ice, but sufficient to furnish a foundation for the snow to accumulate upon. When this accumulation became great enough, the same result as above described will follow. It will begin to be acted upon by the earth's centrifugal force, which has a tendency to tear it loose from its moorings and cause it to

move toward the equator, which is exactly the direction in which it *did* move during the time glaciation was going on, as is shown by the glacial scratches and grooves which are found over the drift region.

The ice would continue to move in this direction until it came to open water, when the end of it would be broken off and floated away as icebergs.

From the topography of the country at the time of the Glacial Period, open water was reached much sooner on the eastern hemisphere than upon the western. The steppes of Siberia — a vast continental plain — are now but two hundred and thirty feet above ocean level. At the time of the Glacial Period this region was all under water, and served as an outlet for the icebergs to float away. But on the western hemisphere the condition was different. There was no open sea to furnish an outlet for the icebergs, and the ice continued to accumulate and to advance upon the land. At this time the whole of the bottom of the North Atlantic, as far south as the southern border of the telegraph plateau, was above water and was being ground by glaciers the same as the rest of the glacial territory.

The glacial region, as described in Chapter XIV., includes an area of about four million square miles in North America and two millions in Europe. (Upham.) To this may be added the region of the North Atlantic, making several millions more covered with the ice sheet (and we do not know what accumulations there might have been in the Antarctic

regions). To make this enormous quantity of ice would require the abstraction of a large amount of water from the ocean. It is estimated that the withdrawal of this amount of water would lower the surface of the entire ocean over the world at least one hundred and fifty feet. (Upham.) Prof. Croll makes it greater than this; but we want to be on the safe side, so we will let it go at that. Then another factor comes in, which is the attraction of the ice itself, which would draw the remaining water toward it and pile it up, thereby raising the surface of the ocean around the ice and depressing it in distant places.*

It has been estimated that these two factors would make a difference in ocean level of two or three hundred feet. Here we have two or three hundred feet of water taken from other places on the earth's surface and piled up around the ice to assist in unbalancing the earth. Then, again, the northern elevation of the land so frequently spoken of by geologists, and which, from the evidence, no doubt existed, would itself be a load. Any elevation on the earth's surface above water level is a load. It has been said that the mountains on the earth are no greater an unevenness, in proportion to the size of the earth, than grains of

* A phenomenon similar to the one above described is witnessed at the mouth of the Indus, at the Bay of Bengal. Here it is found that the water of the bay is five hundred and fifteen feet higher than at Cape Comorin. This piling up is produced by the attraction of the great mountain masses and high table lands of Central Asia. (Enc. Brit.)

sand would be on the surface of an orange; but if an orange were exactly balanced on a pivot, a few grains of sand might unbalance it.

The northern elevation was itself a load, and a big one, too, the size of which we have no means of estimating, but it contributed its part toward producing the catastrophe which followed. The effect of all this accumulation of matter upon one side of the pole, and no accumulation on the opposite side, but, on the contrary, a withdrawal of a portion of the water of that side, would be to antagonize the earth's rotary motion. If the matter should continue to accumulate, the point would finally be reached at which the centrifugal force of the earth's rotations would hurl it toward the equator, or the earth itself would have to tip; *i. e.*, the whole mass of the earth would have to adjust itself to the stable axis in order to effect an equilibrium.

It must be borne in mind that matter in the polar regions near the earth's axis is not affected by the earth's centrifugal force to the extent that it would be affected were it further from the axis. The same ice cap that would not be affected by the motions of the earth to any great extent while it remained near the poles, would, by moving southward, finally get so far from the axis that the effect would be doubled and quadrupled. Yea, if we could keep on increasing the distance between the matter and the earth's axis, it would not have to go very far outward until the centrifugal force would be so great as to hurl the matter

outward into space, in the same way that mud is thrown from a revolving buggy wheel, or water from a grindstone. Apropos to this, articles weigh less at the equator than at the poles, and if the earth revolved seventeen times faster than it now does, they would weigh nothing at the equator, and the tendency would be to fly outward into space.

It appears that ice accumulated in the polar regions will not only have the glacial movement toward the equator, but as it moves in this direction it is getting farther and farther from the axis of motion, and thus the power of the centrifugal force is being correspondingly increased, and the glacial movement is also increased according to the law of accelerated motion; *i. e.*, the ice along the border not only has its own glacial movement, but this is being increased by the pushing of all the mass behind it.

As this ice can not, on account of the earth's attraction, fly off into space, and as the action and reaction are equal, it is pulling upon the earth with the same amount of force that the earth pulls upon it, and has a tendency to pull it over; *i. e.*, to cause the side of the earth to move past the axis until the balance is restored. This would not occur if the earth were equally loaded on the opposite side, but it was not, as above shown.

In order to fully understand this movement of the earth past its axis, and to avoid confusion with those writers who have tried to figure out a change of the earth's axis, it will be necessary at this point to

digress a little and enter into a discussion upon the inertia of matter. Many persons have an erroneous idea about what is meant by inertia. The usual idea is that matter is very obstinate, refusing to move or yield to any force applied to it. This is erroneous. Matter is not obstinate. It is very tractable. It is the easiest thing in the world to move matter if there is no opposing force. When we attempt to move a thing on the earth's surface, the attraction of the earth is the real obstacle to be overcome. That being done, the matter moves easily. If one had a foothold in some other part of the universe, he could with a thread attached to the earth pull it to him, if there was nothing pulling backward upon it. It is that pulling backward which is the real difficulty. If we were to attempt to change the earth's axis, we would find that its rotary motion would refuse to yield. If the force applied comes in opposition to this, then we meet an insurmountable obstacle, and the force applied will have to be in some way commensurate with this, if we expect to effect any change. This is on the supposition that our force in some way is in opposition to the rotary force of the earth upon its axis. Thus those scientists who have shown the difficulty in effecting a change in the earth's axis have been calculating one force in opposition to the other, but we are not calculating it that way. We are dealing with the original force of the earth's rotations, which, we claim, is powerful enough to continue its sway against all obstacles. It will assert its suprem-

acy even if it has to change the position of the entire matter of the earth to do it.

The force of the earth's diurnal rotations must have entire sway, and matter will have to adjust itself to that force.

Will it be said that the equatorial protuberance will counteract this and hold the earth steadfast? Will any accumulation of matter on one side of the earth have to exceed that in mass before the position of the earth could be changed? This at first glance seems plausible, but it will hardly bear investigation. The equatorial protuberance is supposed to be balanced in the beginning; *i. e.*, equal on both sides of the earth. Then any loading on one side of the axis, with nothing compensating on the other side, has a tendency to disturb the equilibrium between the equatorial protuberances on opposite sides of the earth. The effect would be the most pronounced when the load is placed half way between the equator and the pole, or at latitude forty-five degrees. Here, to tip the earth clear over, the load would have to be greater than the equatorial protuberance; but I am not supposing that the earth tipped clear over. I only claim it moved a certain distance from its original position. Now, it seems to me that if a load on one side of the earth, greater than the equatorial protuberance, would suffice to tip the earth a certain distance, then a smaller load would tip it a less distance — a distance in proportion to the mass of the load compared to the equatorial protuberances. If it was balanced before,

how could a load do otherwise than change the point of equilibrium? The loaded side will move a certain distance toward the equator; at the same time the equatorial protuberance will move away from it on both sides of the earth, or form an angle with the equator midway between the meridian of the load and the point on the earth directly opposite. As soon as the equatorial protuberance moves away from the equator, the earth's centrifugal force begins to act upon it — *i. e.*, on both sides of the earth — to pull it back again; and, as it is greater than the load, the point is soon reached where it can go no farther — where the two loads exactly balance and restore the equilibrium. This is on the supposition that the equatorial protuberance is solid; but that is hardly true. The surface of it being composed largely of water, it will change its position and allow a greater movement north and south than it would were it all solid. If the rotations of the earth continue, I can see no chance for an equilibrium without effecting a compromise between the two loads, and the earth will have to change its position in reference to its axis in order to do that. If you will put a load on the equatorial protuberance on one side of the earth, at or near the equator, or spread it along a half meridian with the equator as a center, the earth's rotations will not tip the earth, but the axis will be changed from its original position a distance in comparison to the mass of the load with that of the earth, which would

be very small indeed, and the direction of the axis will be parallel to the original. It will continue to point in its original direction in reference to space.

Now, if the latitude of the earth was changed in the manner which I have above indicated, it is plain that when the load which caused the change was removed (when the ice thawed out), the equatorial protuberance would have a tendency to pull the earth back into its original position. It would do so, provided the protuberance was in its original shape; but such was not the condition. The water over the original protuberance had changed its position, and had been piled up to make a new protuberance elsewhere. Hence, only the solid matter of the protuberance would remain to be acted upon by the earth's centrifugal force. With this change in the original ballast, it could not be expected that the centrifugal force of the earth would pull the mass clear back to its original position. A partial readjustment is all that could be expected under these changed conditions, and all that was accomplished, as is shown by the evidence furnished by the elevated beaches and coast lines which are found over the drift region, and to which allusion will again be made when we come to consider the evidences that the earth has toppled.

At the beginning of the Champlain Epoch there was a readjustment of matter to the stationary axis of the earth. *North America and Western Europe moved down out of the cold region, while Northern*

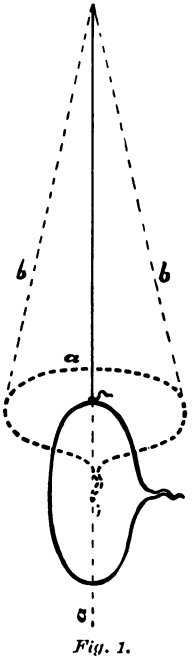

Fig. 1.

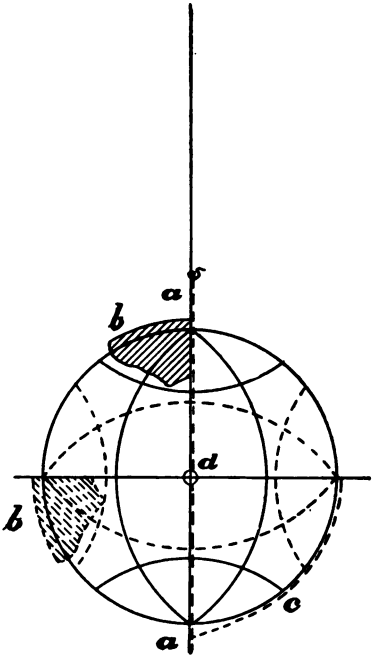

Fig. 2.

Fig. 1. A turnip suspended crosswise with a string, and given a high rotary motion from allowing a tightly twisted string to untwist, will change its position, the axis of motion remaining stationary. (a) axis; (bb) position of string when the turnip has changed.

Fig. 2. A solid globe loaded near one pole with lead. To construct one like this take an ordinary croquet ball, saw it in two at center. A saw with a wide set is best. About the sixteenth of an inch should be taken away across the center. The two hemispheres should then be fastened in as near their original position as possible, leaving a small space between them so that the globe can move transversely to the axis. Put a small rod through it and fasten at d, fasten a string to the rod at s. (a) axis; (b) load; (d) pivot. This will represent the earth's axis. A delicate piece of rubber (c) fastens the south pole to axis so as to hold the load perpendicular near the north pole. Twist the string attached to the rod and give the globe a high rotary motion. The rubber stretches and the load comes down to the equator, as shown in the figure. When the motion dies out the load rises to its original position.

Siberia, on the opposite side of the earth, moved up into it. A slight and imperceptible movement in this direction had, no doubt, been going on for ages, as the load accumulated on one side of the earth, but at the time of which I am speaking something broke loose and precipitated a rush. A cataclysm was produced that submerged the North Atlantic region and southern part of the United States, and carried the earth beyond the point of equilibrium. Of course, the balance was finally established by the waters of the ocean, which, being free to move, rushed upon the land in the form of great tidal waves, which surged back and forth for a time, but finally settled down to a state of tranquillity, while the diurnal revolutions of the earth went grandly on upon the old axis, with perhaps a slight break or variation from its usual regularity. Such would be, not on account of any change of axis, but on account of the transference of force. Some of the earth's centrifugal force having been used in effecting the equilibrium, would necessarily be withdrawn for a time from the diurnal revolution, but as soon as the equilibrium was established, no force being lost, it would return whence it came, and the old motions of the earth would resume and continue in the future as in the past.

That portion of the glacier which rested upon the bottom of the North Atlantic was immediately raised by the inrushing water and floated away as icebergs, and the circulation of the ocean across the north pole,

which for a long time had been interrupted, was restored.

The portion of the glacier which rested upon land of more elevation was slowly melted by the heat of the sun, which was now more direct, forming the water that made the great floods which swept down our rivers, bringing with it sand, gravel, bowlders and other materials that are found in the river terraces. The restoration of the oceanic circulation across the pole, as above described, very materially assisted in ameliorating the climate of the northern regions.

All writers are agreed that the Champlain Epoch was noted for floods and inundation, and they are pretty well agreed that during it the ice disappeared from the glacial area, but they have very erroneous ideas as to what effected this change. The most prominent theory advanced to account for the amelioration of the climate, which caused the disappearance of the ice, is that the crust of the earth was so loaded down by the weight of the ice that it bent beneath its load and settled down. The effect of the difference of altitude would ameliorate the climate and produce the other phenomena pertaining to the Champlain Epoch. Then, after the ice thawed out, the crust raised up again. A very ingenious theory, but hardly probable. Is it possible that such a bending of the crust could have taken place among our rocks and leave no trace behind? Has any one found the place of the bending? Then, again, what

produced the cold to form the ice, and why did the cold not return when the surface rose up again? Such explanations only complicate the subject and render it more difficult.

The cause of the unbalancing of the earth and the Champlain Epoch will receive further attention in a future chapter.

CHAPTER XVI.

EVIDENCE THAT THE EARTH HAS TOPPLED.

The glacial region, as described in Chapter XIV., extends but half way around the globe. On the opposite side of the earth there was no glacial action in the northern hemisphere. Do you want evidence of this? Have you ever read of the Siberian mammoth which was found frozen in an ice cliff at the mouth of the Lena River? It was one of the Tertiary animals which perished in the cataclysm that attended the tipping of the earth. It was so well preserved in the ice that dogs ate of its flesh. Portions of the animal are now on exhibition in the Royal Museum at St. Petersburg.* In company with the

* There has recently been another discovery of a preserved mammoth in the ice of Eastern Siberia. The Russian newspapers published the following official telegram dated Yakutsk, December 28th, 1901: "The expedition which was sent out by the Academy of Sciences, under the Zoologist Hertz, to examine the mammoth remains discovered in the District of Kolymsk, has reached Snende, Kolymsk, after a very difficult journey, bringing the mammoth with it. The animal was a male, and apparently middle-aged. Its skeleton and skin have been preserved nearly intact. It was lying down, with its feet curiously bent under its body. The tail was short and covered with long hair. In the stomach, between the teeth and on the tongue remains of undigested food were found. The different parts of the mammoth have been conveyed to St. Petersburg, in a frozen condition. (Nature, January 9, 1902.)

mammoth, the carcass of a woolly rhinoceros was found. Mammoths were animals nearly twice the weight of elephants. They had curved tusks nearly twelve feet long. The heads and tusks of mammoths were so abundant in that region that they long supplied all Russia with ivory, besides contributing a large amount to export to foreign countries. In 1872 and 1873 as many as 2,770 mammoth tusks were entered at the London docks that came from this region. (Wright.) Many of the rivers of Northern Siberia approach the ocean between solid cliffs of perpetual ice that rest on frozen ground, and it is in this ice that the remains of those extinct animals have been preserved.

The frozen alluvial deposits near the mouths of these rivers are literally packed with the remains of mammoths, woolly rhinoceri, bisons and horses. So abundant are the remains of mammoths that for many years the cliffs have been quarried for the sake of the ivory they contained. (Geike.) Here, then, is a sepulcher of Tertiary animals. Their remains have been preserved by the "cold process." There has been no glacial action in this locality, or this sepulcher would have been desecrated. These remains would have been ground to powder or carried away and buried in the drift such as we find in the glacial field. How did the remains of these animals get into the ice? It has been a great puzzle to scientists to account for the Glacial Period, when once fairly

inaugurated, passing away, or to account for the ice disappearing over the glacial field; but I see nothing more difficult in that than to account for these animals, the congeners of those now inhabiting a tropical climate, being found frozen in the ice cliffs of Siberia. One is a counterpart of the other. It is plain that when the west side of the earth warmed up, the east side became cold, and it is also plain that the transition was sudden, the animals being either frozen to death or drowned in a cataclysm that accompanied the change, and then frozen so quickly that decomposition had not time to do its work. Were these animals found in ice cliffs in the southern hemisphere, it might with good reason have been claimed as a fact to sustain Croll's theory; *i. e.*, that, by the precession of the equinoxes, the winter of the ages was transferred to the southern hemisphere, while the northern was warming up; but when we find this chilling process on the same side of the equator that contains the glacial field, and while the latter is becoming warmer, here we find things freezing up. It could not have been brought about by the precession of the equinoxes, for if that had had any effect at all, it would have been to transfer the cold area to the southern hemisphere. This fact is fatal to Croll's hypothesis.

It seems that when the east side of the earth tipped northward, the reaction caused a great tidal wave that caught the animals which roamed over the

regions south of and adjacent to the then northern ocean, and carried them away as drift, to become frozen in the ice, and there they have remained ever since. Here is the evidence that there was a rush, as described in Chapter XV., at the ushering in of the Champlain Epoch.

In the year 1900 Prof. Wright crossed Siberia, going from China to Europe. He says concerning this trip: "As Asia, like North America, stretches toward the north pole and faces a great sea on the east, I naturally expected to find there evidences of a glacial period similar to that in this country. But, contrary to all my expectations, I found no sign in Central Asia and Southern Siberia of glacial work."

Here we have it stated by competent authority that the glacial region does not extend over Southern Siberia, and we have the evidence furnished by the remains of the Tertiary animals deposited at the mouths of the great rivers in the north, as above mentioned, that it did not extend over Northern Siberia; therefore, it was on but one side of the earth in the northern hemisphere. Tell me, ye advocates of Croll's theory, how this could have been. If the eccentricity of the earth's orbit two hundred and forty thousand years ago was lengthened by ten millions of miles, and produced a glacial period, tell me why the chilly atmosphere should affect the earth on the western hemisphere and leave a mild climate on the eastern. Croll's theory is very ingenious, and very

scientific, but it has one defect in it. *It does not fit the facts in the case.**

The facts above stated also refute the carbonic acid theory. If the climate that glaciated North America and Europe was brought on by the abstraction of the carbonic acid of the atmosphere, tell me what protected Northern Asia. How could the supply of carbonic acid be extracted from the atmosphere over the area of the drift region and leave the opposite side of the earth undisturbed in its proportion of carbonic acid? Will you say this region during the Glacial Period was depressed to ocean level — the

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* Attempts have been made to explain the absence of glaciation in the central and northern part of Asia on the hypothesis that it was from lack of precipitation. It has been claimed that the principal part of the precipitation which caused the ice of the Glacial Period, came from the Atlantic Ocean, and that only regions contiguous to this ocean were glaciated. In support of this is cited the fact that northern oceans and seas cover with ice when all evaporation is in a measure cut off. Thus no water to make snow is evaporated, and the climate becomes dry. Such is the condition at present of Central Asia.

This argument to explain the absence of glaciation in Siberia might have some weight if it were shown that the same conditions existed at the time of the Glacial Period as at present, but such was not the case. If the reader will refer to the map of the Eastern Hemisphere during the Glacial Period, it will be seen that an ocean existed south of any ice that could possibly have existed, and all the conditions were favorable for evaporation of water to make snow. Hence, if the advocates of this theory admit that this ocean existed as delineated on the map, their arguments fall to the ground.

surface of the eastern hemisphere being lower than the western, the remaining carbonic acid settled here and left the glacial region depleted? To maintain such a claim, it will be necessary to assume a still atmosphere, void of currents to stir up and mix the carbonic acid with the rest of the atmosphere. If this is the assumption, it will upset the glacial theory entirely, for to precipitate snow in sufficient quantities to make a glacier, we must have atmospheric currents. The glacial region, though extensive, was a local phenomenon; whereas, the assumed abstraction of carbonic acid would be a general phenomenon. Hence, the carbonic acid theory is like that of Prof. Croll's, in that it does not fit the facts in the case.

Do you want more evidence of the tipping? We will try to give it. The United States Government Coast Survey has traced out a sunken coast all along the Atlantic border. They have traced the valley of the Hudson River eighty miles to sea. It reaches the ancient border of the sea in water thirty-three hundred and forty feet in depth. For more than twenty-five miles it has a depth of more than two thousand feet from the top of its banks, which have a slope of fourteen degrees. The water over the banks at the mouth is five hundred feet deep. Other channels have been traced from other rivers along the Atlantic border out to this sunken coast. It would be the sheerest nonsense to claim that these channels were eroded while under the ocean. River channels are not made that way. Their existence

proves that the bottom of all that portion of the ocean out to the mouth of these rivers — the ancient coast line — was above water when these channels were eroded. A similar sunken coast has been traced on the east side of the Atlantic. All geologists admit these sunken coasts, but they endeavor to account for them on the supposition that it was done by a slow and gradual sinking, such as has been proved to be going on along the coast of the Gulf of Mexico probably from the weight of the sediment deposited by the Mississippi River. If the Atlantic border is settling gradually, and these sunken coast lines are to be accounted for in that way, would not the sediment of the rivers which have channels under water out to the ancient coast line, have filled these channels as fast as the sinking went on? Certainly it would The very existence of these channels under water proves that the submergence was *quickly done*, else these channels would have been filled with sediment. There is no rational way to get around this conclusion. But what difference does it make whether these coasts were slowly or suddenly submerged? What have they to do with the question at issue, viz.: the tipping of the earth? They have much to do with it. If you will tip the earth backward or northward ten degrees, or six hundred miles, you will bring all these sunken coasts above water. To illustrate, suppose we take a point on the solid crust of the globe even with the water or at ocean level at the north pole and tip it to the equator. Here we find it is thirteen miles

under water. Then again, if we take a point at ocean level at the equator and tip it to the north pole, we will find it thirteen miles above water. This point is so plain that any schoolboy can understand it. Tipping a solid point on the earth southward submerges it, and northward elevates it, and this submergence or elevation is in exact proportion to the distance gone over, always bearing in mind the shape of the earth — that of an oblate spheroid.

Apropos to this, a north and south line, showing a former water level, a beach line, for instance, will by tipping the earth northward become more elevated toward the north and depressed toward the south end; *i. e.*, it will show a slope to the south, and *vice versa* when the earth is tipped toward the south. This will hold good from the equator to the poles, only the conditions are reversed on the south side of the equator toward the south pole.

It was in this way that these sunken coast lines were depressed and the lake ridges of our own land and the Steppes of Siberia were lifted out of water.

If we tip the earth northward a sufficient distance to bring the submerged mouths of the rivers along the eastern coast above water, what effect will it have upon the bottom of the North Atlantic? We will see. Nowhere between Scotland and Iceland is the ocean more than six thousand feet in depth, and most of the distance it is less than six hundred feet. (Dana.) Tip the earth northward ten degrees and all the North Atlantic as far south as the telegraph plateau will be

above water, with the gulf stream shut off from the polar regions and turned southward. Here we have the conditions for a glacial period in the northern hemisphere in perfection, and that is the way it was during the so-called Glacial Period before the earth toppled over and relieved herself of her load.* The glaciation was done while the glaciated territory was farther north than it now is, just as it is being done now in Greenland. The tipping caused the ice to disappear, and thus ended the glacial action over the territory on the western hemisphere, but the effect was not so genial on the eastern hemisphere. After the tidal wave that caught those Tertiary animals in Siberia had subsided, that region became frozen up, and has remained so ever since.

Similar evidence of a tipping of the earth southward is furnished by the buried river channels which are found all over the glacial territory. Many of them are so deep that were the fill removed from the channels it would place the streams below ocean level. The Ohio River throughout its entire course has a buried channel one hundred and fifty feet below present water level. Its tributaries also exhibit the same

* Indisputable evidence that the eastern and western continents were connected together before the time of the Glacial Period is furnished by the remains of the same kinds of animals on both sides of the Atlantic; as, for instance, the bones of the mammoth, mastodon and many other extinct animals have been found on both hemispheres, showing that there must have been land connection in order to give them this range.

phenomena. The Tuscarawas is running one hundred and seventy-five feet above its ancient bed. The buried channel of the Cuyahoga is two hundred and thirty-eight feet below the surface of Lake Erie. The bottom of the buried Mississippi channel between Cairo and New Orleans has never been reached. It is estimated to be down six hundred feet at New Orleans. (See Ohio Geological Report, Vol. XI., p. 17.) Professor Wright devotes one whole chapter of his Ice Age to the description of buried river channels over the United States, but the strange thing is, he does not tell us how they came to be as they are. It is evident that these channels were eroded when the surface of the country was more elevated than at present. If you will tip the earth so as to bring the surface a few hundred miles northward, you will bring these buried channels up to the place they occupied when they were eroded. Tipping a river channel northward or southward has the same effect to elevate or depress it that has been explained in reference to coast lines. These channels were depressed during the tipping of the Champlain Epoch.

Buried channels also exist along the rivers in Europe, and no doubt have their origin in the same cause as those in the United States.

CHAPTER XVII.

THE EVIDENCE CONTINUED.

Is there more evidence that the earth has toppled? I think there is. Have you ever heard of the elevated beach lines along the Atlantic and the lake ridges parallel with the borders of the Great Lakes? If you have not, I will state that such exist. Have you ever heard of the Loess down the Ohio and Mississippi Valleys, and, in fact, over a large part of the southern portion of the United States? It is there, as all authorities testify. What does it mean? Explain it. It means that all the territory covered by the Loess has been under water, and this fine sediment was deposited at that time. How does it come to be now above water? It means that the earth has tipped northward after it was relieved of its load of ice, righted itself—restored the equilibrium. Can I prove this? I think I can. All authors are agreed that this Loess was deposited during the Champlain Epoch—was deposited while the great glaciers were thawing out. Then if we find the line or border of it, we find the line of water level at that time. This has been done. It has been found near Cincinnati to extend to an altitude of one thousand feet above ocean level, while near Pittsburg it extends up to eleven hundred feet, *becoming more elevated as we go northward.*

The same thing holds good of the lake ridges.

They mark ancient beach lines on the south side of the Great Lakes. There are none on the north side. At the time they were made, the St. Lawrence was blocked by the retreating glacier, and the water was dammed up until it found an outlet across the divide southward into the Ohio, and later across New York into the Hudson. Lake Erie has three ridges, and at places other intermediate ones have been observed. At the west end of them they have an altitude of from one hundred to two hundred and thirty feet above the present level of Lake Erie. They have been traced several hundred miles. The upper beach is practically horizontal from the Maumee Valley near Defiance, Ohio, eastward to Geneva, in the northeast part of Ohio; this line being nearly along a parallel of latitude, but at Geneva it bends northward, and here it begins to rise, and continues to increase in altitude to Sheridan, N. Y., where it has risen one hundred feet. This rise continues to Hamburg, N. Y., where it is one hundred and thirty feet above its western extremity, then it runs out into a moraine, the supposed place where it met the ice sheet. (Leverett, in United States Geological Survey.) The other lake ridges show a corresponding raise toward the north. Shall we think this ancient body of water had a sloping surface of one hundred feet? Not at all, but the earth has slightly tipped northward when relieved of its load — straightened up — that is all there is of this.

There is an elevated beach line along the eastern

coast of the United States. Its elevation in Southern New England is fifty feet. At Boston one hundred feet. Along the coast of Maine it is two hundred and thirty feet. At Montreal it is five hundred feet,* and from one thousand to sixteen hundred feet in the extreme north of the continent.

Scientists have furnished us with two theories to account for the slope of the elevated beach lines and lake ridges. Professor Le Conte thinks the crust of the earth had been bent downward by the weight of the ice when these beaches were made. It afterwards raised up when the ice disappeared, bringing these beaches into the position in which we find them. Professor Croll thinks the water of the ocean and that of the lakes were attracted toward the great ice sheet — piled up, as it were, giving the sloping surface that we now find marked by the beach lines. (See note, p. 109, Chap. XV.)

Either of these theories might explain the elevated beach lines were they all there is to explain, but they do not explain how there came to be such a great body of ice as to either pile up the water by attraction, or bend the earth's crust by its weight; neither do they explain the sunken coasts which have been heretofore described. (See p. 125, Chap. XVI.) We will have to get some theory that will explain all the phenomena, or it will necessitate another theory to explain the remaining. It seems to the writer an

* The slope of this beach from Boston to Montreal is two feet to the mile. (Wright.)

easier way out of the difficulty would be to admit a slight tipping of the earth toward the north, just a little, or sufficient to bring these coast lines and lake ridges just where we find them. The earth partially righted itself after the ice thawed out, but the water of the equatorial protuberance having changed its position, the solid part of the protuberance was not of sufficient size to bring the earth entirely back to its original position. Hence the drift region still lies farther south than it originally did, and the sunken coasts are still under water.

The most of the terraces along our streams can be explained in the same way. The materials composing them were deposited during the depression of the Champlain Epoch. They were raised to their present position by the northward tipping when the ice disappeared. Since then the streams have been gradually cutting their channels downward again, leaving the terraces which mark former water levels or river beds.

Before dismissing the subject of the elevated beaches, I will call attention to another defect in Croll's theory. On the hypothesis that the elevated beaches were made by the water attracted to the ice sheet, piled up, as it were, we thereby get open ocean from the ice sheet to the equator. The deposit of Loess indicates the same thing. What would be the effect of this? The warm water of the equatorial regions would melt the ice or prevent its forming. Professor Croll thinks that the great accumulation of

ice during the Aphelion winters, when the earth's orbit was most eccentric, will have the effect to divert the ocean currents principally toward the southern hemisphere, leaving the waters of the northern hemisphere to become chilled. In this way, he thinks, ice formation was very much facilitated. Is there any foundation for this supposition?

Investigation by soundings has shown that all the waters of the oceans below the four-hundred fathom line is at present chilled down to near the freezing point of fresh water, and some places it goes below the freezing point, as has already been explained. This low temperature in the bottoms of the oceans is owing to the polar currents, which have crept under the warm water of the surface. That of the Pacific and Indian Oceans comes from the Antartic regions, while that of the Atlantic comes from both north and south. So positive is this decrease of temperature at bottom of open ocean that any variation from it is indicative of a reef or ridge which has shut the cold water out, and by this indication such ridges have been located. (See Encyclopedia Britannica.)

Now if the cold water will creep under, warm water will have to move to the source whence the cold water came. In other words, there can be no polar currents moving along the bottom of the ocean toward the equator without a surface current of warm water moving in an opposite direction. If such a circulation was going on in the ocean, how could an ice

sheet form and move into a temperate zone down to latitude 37° 30′? How could it do that with water piled up south of it, making open water from the edge of the ice sheet to the equator? Will it be said the water was too shallow to allow the cold currents to creep under? Then how about the waters of the Atlantic, which is deep enough now to allow the cold current to creep under, and of course then it was still deeper by the piled up water? So, if it is admitted that the elevated beaches were made by the water attracted to the ice sheet, by the same process of reasoning we can prove that it would have been impossible for a glacial period to have existed at all, for the waters attracted to the ice sheet would have facilitated ocean currents from the tropical regions to clear the ice away as fast as it formed. It seems more reasonable that a different condition existed when this ice was formed, and when the waters piled up around it, then the ice began to disappear. The ice approached the waters principally by the tipping process instead of the waters approaching the ice by attraction, although the latter process no doubt did have an influence in regulating the line of ocean level. The earth tipped southward to meet the water, but when relieved of its load of ice, it then partially righted itself by a northward tipping.

There is a matter on the opposite side of the earth which should be explained. It is the Loess of Central and Eastern Asia. Professor Wright found it in

some places one thousand feet thick; at other places it extended to an altitude of twenty-five hundred feet.* This Loess was deposited at the bottom of still water, and from the amount of it and the altitude to which it extends, the water must have been deep. Also from the thickness of the deposit, the submergence must have lasted a long time. It seems to me to be utterly untenable to claim that such immense deposits are the counterpart of those deposits of Loess which are found in the Mississippi Valley. There is too much contrast. Rather would it appear to be a counterpart of the sunken coasts that have been traced along the eastern border of the United States. In other words, when the western side of the earth tipped down and sunk these coasts, the eastern side tipped up and raised the territory of the Asiatic Loess out of water.

* Professor Wright says: "For several hundred miles, while driving through the regions south of Lake Balkash and at the Aral Sea, we were evidently upon a terrace of the fine loam which is called Loess, about twenty-five hundred feet above sea level. Indeed, at different elevations this Loess extends continuously in a broad shelf along the base of the mountains from the Irtish River to the Caspian Sea, and is found in extensive level areas over various portions of the Caucasus and Northern Persia, around the base of Mount Ararat." (McClure's Mag., June, 1901.) Professor Wright gives the altitude to which he, too, observed this Loess (twenty-five hundred feet), and a singular coincidence is furnished by the depression of the sunken coast and valley of the Hudson, near New York, which shows a depression at that point of at least twenty-five hundred feet. These two points are nearly in the same latitude and on opposite sides of the earth.

To erode the valleys in the sunken coasts of the borders of the Atlantic, it must have required an immense lapse of time. The same can be said in reference to the time required for the deposits of the Asiatic Loess. Both appear to have been going on during the Glacial Period, and the culmination of both was at the ushering in of the Champlain Epoch. The Asiatic Loess could not have been deposited during the time of the Champlain Epoch in the western hemisphere, for that did not last long enough. The conditions in Asia are just as we should expect to find, if they had come from the bottom of the Ancient Ocean which was destroyed when the earth toppled from its original position.

A question might be asked as to where was the outlet on the western side of the ocean which covered Central Asia and the Steppes of Siberia.

The accompanying map gives a good idea of the position of land and water on the eastern hemisphere at the time of the Glacial Period. Here it is shown that the Northern Ocean covers nearly all Siberia, and comes down to near the thirty-sixth parallel; before the northward tipping it came down still farther, say about to the thirtieth parallel from the then equator. This position of the Northern Ocean does away entirely with Behring's Strait, leaving an open ocean from the Pacific to the polar regions. Also it shows the connection in the south and west between the Northern Ocean and the Indian and the Atlantic Oceans, giving ample channels for the pass-

EASTERN HEMISPHERE DURING THE GLACIAL PERIOD.

age of icebergs, etc. All authorities are agreed that the Caspian Sea was connected with the Mediterranean. "The shells are chiefly the same as those still living in the Black Sea. Banks of them may be traced between the two seas, with salt lakes and marshes and other evidence to prove, not only that the Caspian Sea was once joined to the main ocean, but that a great firth ran up between Europe and Asia, and possibly stretched completely across what are now the Steppes and Plains of the Tundras, till it merged into the Arctic Sea." (Encyclopedia Britannica. See article on Geology; also on Caspian Sea.)

As the Caspian and Aral were connected with the Black Sea — that now being connected with the Mediterranean. If the Mediterranean did not exist at the commencement of the Glacial Period, then the connection was with the Sahara Sea. At any rate, there was a connection between the Northern Ocean southwestward with the Atlantic, giving an outlet for icebergs southward at each extremity. The Caspian, Aral and Dead Seas are now all below ocean level, and are perhaps remnants of bays connected with the Ancient Ocean. The Steppes of Siberia are but two hundred and thirty feet above ocean level. A very slight tipping of the earth southward on the eastern side — straightening it up, as it were — would suffice to restore this Ancient Ocean. No wonder the north coast of Siberia froze up when this Ancient Ocean was destroyed.

Behring's Strait was lifted clear above water and southern currents shut off from the polar regions. It was partially restored in the backward tipping at the close of the Champlain Epoch, but it is still very shallow (one hundred and fifty feet).

The topography on the eastern hemisphere during the Champlain Epoch was as much in a condition to freeze things up as the western hemisphere would be at present were the North Atlantic lifted out of water and the gulf stream shut out from the polar regions. The result would be a sudden chilling of the north part of the western hemisphere and a rapid extension of the ice area.

I should hardly do justice were I to dismiss the subject without mentioning the south polar regions. In the present state of our knowledge of glacial action in the southern hemisphere, it is impossible to tell what assistance might have been given to this toppling of the earth by ice accumulated around the south pole. There appears to be sufficient evidence in the northern regions to account for all the phenomena of the toppling of the earth from the ancient position, but we must not slight the southern regions.

It appears that the land of the globe is principally gathered together in the northern hemisphere — an excellent foundation for ice to gather upon to load the earth to the condition of toppling. The principal water of the world is gathered in the southern hemisphere, an excellent medium for transporting icebergs, thereby preventing overloading. The condi-

tions about the south pole do not seem to indicate that any great assistance in the matter came from that quarter. The evidence seems to indicate that during the time of the Glacial Period the currents of the oceans were shut out of the north polar regions, and if that supposition is true, they must have gone somewhere else, and where could they go but to the south polar regions? If the gulf stream and all the other warm water of the tropics was diverted southward — was poured into the south polar regions, with the undercurrents from those regions compensating this, the south polar regions could not have been very cold. Probably the Antarctic Continent as it now exists is a point raised from beneath the ocean by the tipping of the Champlain Epoch, and this accounts for its lack of inhabitants, for it is said that no land quadruped has been found upon the Antarctic Continent, and also for its lack of fiords and indentations. (See note, p. 89.) The waters of the ocean would no doubt still possess a large portion of this continent were it not that they have been crowded back, perhaps in places hundreds of miles, by the wall of the advancing ice sheet. Were a sheet of equal thickness advancing from the Arctic regions, it would be sufficient to displace the greater part of the waters of the North Atlantic.

But suppose the Antarctic Continent existed at the time of the Glacial Period, as it does now — if the ice sheet around the south pole was in the beginning equal or balanced on both sides of the pole, as it is

supposed to be at present, any movement of the earth produced by the unbalanced ice accumulations around the north pole would soon throw the Antarctic ice sheet out of balance, and the effect would be doubled from the beginning, for as the earth tipped the Antarctic ice sheet would be getting longer on one side (farther from the pole) and shorter on the other, and thus the northern load would be assisted in unbalancing the earth. But we have some evidence from south of the equator and on the opposite side of the earth. Mark Twain is not generally considered a scientist; yet when he states a matter as a fact or claims he saw a certain thing, I know of no author whom I would be more ready to believe; and from his experience while mining in the West, his judgment in interpreting phenomena is entitled to considerable weight. Hear what he says (Following the Equator, p. 234). Speaking of the soil and mining at Ballarat in Victoria (the extreme southern part of Australia): "They went down into the earth with deep shafts seeking the gravelly beds of ancient rivers and brooks, and they found them. They followed the courses of these streams, and gutted them, sending the gravel up in buckets and washing out of it enormous quantities of gold."

Here is described the complement of our buried river channels. The locality is almost exactly on the opposite side of the globe and on the south side of the equator. They probably were buried by the

northward tipping of that locality, corresponding to the southward tipping in this locality.

The testimony in reference to raised beaches in Tasmania corresponding to ours, I take from the Encyclopedia Britannica, article on Tasmania: "Raised beaches are noticed along some of the larger rivers, and westerly moraines would imply a former greater elevation of the country."

What better evidence than this do we need to show that the conditions south of the equator, on the opposite side of the earth, are just as we should expect to find them had the earth toppled as explained in Chapter XV.?

Thus it is seen that the solid crust of the globe withstood the change of latitude without bending or changing its shape to any great extent. The only change observable was in the liquid outside of the crust — the waters of the ocean — the changes in this being marked by elevated beach lines and sunken coasts and channels, showing former water levels. The equilibrium was mainly brought about by a change in the position of the water of the earth, the axis remaining in its original place as regards to space, always pointing toward, or nearly toward, the north star.

CHAPTER XVIII.

OBJECTIONS CONSIDERED.

The idea that a load on one side may have had some influence in changing the position of the poles and the latitude of the earth has been considered by some of the world's greatest scientists, and they have come to the conclusion that such a change in an appreciable degree would have been impossible; as, for instance, Sir William Thompson has estimated "that an elevation of six hundred feet over a tract of the earth's surface one thousand miles square and ten miles in thickness would only alter the position of the principal axis by one-third of a second, or thirty-four feet" (Encyclopedia Britannica). I claim that it would not alter it at all. (See Chapter X.) The axis would remain stationary, but the earth would have to adapt itself to this load by a slight tipping, which could not be very great on account of the resistance of the equatorial protuberance. If the earth were an exact sphere and rigid, it would tip it clear to the equator.

If Sir William Thompson means that this load would alter the position of the earth in reference to its stationary axis, then he admits at least that a load on one side of the axis will cause the earth to adjust itself to that load, and that is exactly what I claim, even though the change of position of the earth to

its axis be ever so little. This admitted, it follows as a corollary that if the load kept on accumulating, the change would accordingly increase. It could not be otherwise.

"Mr. George Darwin has shown that on the supposition of the earth's complete rigidity no redistribution of matter in new continents could ever shift the pole from its primitive position more than three degrees, but that, if its degree of rigidity is consistent with a periodical readjustment to a new form of equilibrium,* the pole may have wandered some ten or fifteen degrees from its primitive position (*i. e.*, the earth may have moved — the pole, which is the end of the axis of motion, remaining stationary), or have made a smaller excursion and returned to near its old place. In order, however, that these maximum effects should be produced, it would be necessary that each elevated area should have an area of depression corresponding in size and diametrically opposite to it, that they should lie on the same complete meridian, and that they should both be situated in latitude 45°. With all those coincident favorable circumstances, an effective elevation of 1-300 of the earth's surface to the extent of ten thousand feet would shift the pole 11 1-3′; a similar elevation of 1-20 would move it 1° 46½′; of 1-10, 3° 17′; and of ½, 8° 4½′. Mr. Darwin admits these to be superior limits to what is

* Would not a continued accumulation of ice work the same—*i. e.*, require a periodical, or constant readjustment?

possible, and that on the supposition of intumescence or contraction under the regions in question, the deflection of the pole might be reduced to a quite insignificant amount." "Under the most favorable conditions, therefore, the possible amount of deviation of the pole from its first position would appear to have been too small to have seriously influenced the climates of the globe within geological history. . . . There seems indeed to be no geological evidence in favor of any such geographical changes as could have produced even the comparatively small displacement of the axis (pole) considered possible by Mr. Darwin." (Encyclopedia Britannica.)

The above is the conclusion of eminent scientists, arrived at after careful and laborious mathematical calculation, but does that settle it? Does that explain what caused the Glacial Period? It seems almost useless for scientists to claim theoretically that a thing could not occur when the evidence plainly indicates it did. For the sake of argument we will admit that by the slow and gradual accumulation of ice on one side of the earth and the withdrawal of water from the other side, it would have been insufficient to have produced the effects which we observe. If any effect at all was produced in this way, it would have been by slow degrees. The movement would have been going on slowly as the ice accumulated, and might have become perpetual, unless something intervened to change it. It is evident that as long as this condition continued, no such phenomenon as a Champlain

Epoch could occur. The ice would keep on forming and moving southward until it met with warmer winds and water, which would have checked the farther advance or melted it as fast as it reached such point. North of this point the ice would have continued to form, and the drift area would still be covered with ice. We would have had no Champlain Epoch to clear it away. The evidence shows conclusively that there was such an epoch, for the field is now mostly clear. What brought this about? It is plain it could not have been done by the slow process as above described. In order to produce the phenomena of the Champlain Epoch, there must have been a rush. Something gave way, or precipitated the unbalancing of the earth. What was it? I can only conjecture.

If the earth had for perhaps thousands of years been subject to a slow but gradual change transversely to its axis, the solid equatorial protuberance would finally come to a point where it would not fit over the nucleus within. An arch would be formed. Such would be the inevitable result of this slow and gradual tipping of the earth from the weight of ice on the opposite side. Should this arch give way suddenly, the revolving sphere would be suddenly unbalanced and a rush would come.

Will you claim that if such a collapse should occur it would be attended with a slow motion similar to the other? Then you deny the possibility of an earthquake. I see no reason why such a collapse might

not have been attended by an earthquake, and as sudden a one as has ever occurred, and then the rush would come. Even the load of ice which once occupied the drift region, could it have been suddenly applied, allowing no time for the earth to adjust itself to it, would have precipitated a tremendous rush, that would have carried the earth clear beyond the point of equilibrium. The same result would follow were there any sudden lightening, removal or collapse of the ballast on the opposite side of the earth.

A slight down-sinking of the bottom of the Indian Ocean and perhaps some parts of the Pacific would have been sufficient to have precipitated the unbalancing of the sphere, and at the same time the Himalaya Mountains were probably much increased in height. It is a significant fact that this is the only great mountain range of the world that extends in a direction east and west. The formation is also one of the most recent. As the direction of this great chain is different from that of the others in the world, is it not reasonable that the strain which produced it came from a different direction than that which upheaved the other great mountain chains? Is there any more reasonable hypothesis to account for the direction of this range than the one above suggested?

If the equatorial protuberance gave way suddenly on the opposite of the earth, there would be nothing to prevent a rush, which would not be checked until the collapsed or smaller ring became balanced with

the load. The rush would carry the earth past the point of equilibrium and cause the waters of the oceans to change their places and assist in forming a new equatorial protuberance, which would not correspond with the old. When the equilibrium finally became established, the earth would be in a changed position in reference to its axis, and the glacial region which contained the load would have been moved nearer the equator.

All we need to fully account for the phenomena of the Champlain Epoch is, first, a load on one side of the earth sufficient to produce a strain, and, secondly, an earthquake to precipitate a rush, and the thing is done. The Champlain Epoch is ushered in.

To recapitulate: If there was any movement of the mass of the earth past its axis (as admitted by scientists to have been possible), whatever movement there was would be a strain upon the equatorial protuberance on the opposite side of the earth. If the arch of this exactly fit the nucleus before this movement began, it would soon reach the point where it would not fit, and a suspended arch would be formed. Should this give way, a settling, a crumpling together, and the usual phenomena of mountain-building, such as earthquakes, etc., would result. When this violent seismic action had subsided, it would be found that the surface of the earth, in reference to its stationary axis, was in a changed position, and the glacial field had been moved nearer to the equator, with a like read-

justment of surface on the opposite side of the earth, all of which seems to correspond with the evidence as we have heretofore presented.

Now if this unbalancing of the earth actually occurred, a question arises as to whether some evidence of that motion ought not still to remain in the form of secular vibrations.

Mr. G. C. Compstock (Amer. Jour. Science, Dec., 1891,) made some observations which, if confirmed, would show that the earth has a slight secular change of latitude. By comparing the records kept by several different observatories, made from year to year, to determine the exact latitude of the place where the observations were made, he came to the conclusion that they all showed slight secular variations of latitude, but the variations were so slight as to be scarcely appreciable, and might have resulted from inaccuracy in observation.

Whether such vibrations still remain or not to remind us of a former toppling of the earth will require further and more careful observations, extending over a considerable number of years, in order to accurately determine this point. But if, when determined, the result should be negative, it will not prove that the above described movement of the earth did not occur. It will only show that if it did occur, the time was so remote that the vibrations have completely died away. Thus it might furnish some data for astronomers to figure upon, to show that the Glacial Period could not have been very recent, or the

vibrations from the toppling of the earth would still remain.

My own opinion upon this question is that the vibrations of such a movement would last but a short time — would not be present now at all. They would have been present and could now be detected were it not for the water on the surface of the earth. The equilibrium after the toppling would have been established mainly by the waters of the oceans, which, being free to move, would counteract any secular vibrations in the solid crust, and by changing their positions would finally bring the whole mass to an equilibrium. Furthermore, if by careful observations, extending over a long series of years, it were shown that places on the earth have a slight secular change of latitude, as claimed by Mr. G. C. Compstock, I would attribute this to changes of the earth in reference to its axis, caused by present accumulations of ice in the polar regions, rather than to the remains of vibrations started by a former unbalancing of the earth.

While looking for evidence in the way of vibrations as reminders of past conditions of the earth, might it not be well to consider the motion of the water in the gulf stream? Does that not furnish grounds for inquiry as to whether it is not due to a cause which existed in the past? Scientists have theorized a great deal in trying to account for its movement northward instead of southward. The shape of the ocean, the rotations of the earth, trade winds, Arctic currents creeping under, have each been

assigned as a probable cause for the surface water flowing northward, and still the question is not definitely settled. Much theorizing has been done as to what would be the effect upon the Arctic regions were the waters of the gulf stream diverted southward, and most of the theories to account for the Glacial Period have been founded upon the supposition that *something* changed the direction of the gulf stream; but before we try to find a cause which would divert it southward, would it not be well to search for the cause of its present northward movement? With a wide open ocean to the southward and more cold water in that direction than in the opposite to creep under, still the Gulf Stream flows northward. A suggestion is ventured to account for this. When the earth tipped southward, as explained in Chapter XV., the tropical waters rushed in and raised and floated away the ice of the North Atlantic. The pent-up waters of the polar regions flowed out and began to mix and creep under the warmer water from the south. Other cold water was furnished by the melting ice, and in course of time a general circulation was established in the ocean — warm water on the surface going northward and cold water in the bottom going southward. In this way the cold of the Glacial Period was in a great measure transferred to the bottom of the ocean.

After a circulation is fairly established in a body of water the size of the Atlantic, it will continue for a long time, and it would require something of con-

siderable magnitude to stop it. The circulation will continue after the cause which set it in motion has ceased to exist.

The gulf stream is a reminder of the work done by the ocean in times past in clearing the northern hemisphere of ice accumulations.

CHAPTER XIX.

AN OPEN POLAR SEA.

An open sea they long have said
Has North Pole, centering in its bed;
And more—when ships far northward go
They pass the drift and iceberg floe,
And reach a calm and open sea
From ice formation ever free.
Yet none have passed the brumal line
That open seas begird, confine.

Is this illusion, false, untrue?
Must we reject the olden view?
Shall youthful idols one by one
Still fall, till age, alas! has none?

A myth that open polar sea?
A myth? Then prove it so to be.

If not, then snows perpetual fall,
As stone on stone build up a wall,
Till oceans, seas, as vapor rise,
And northward drift to polar skies,
There fall as snow, to rise no more,
Till earth itself is toppled o'er.
When North Pole bows to kiss the sun,
An era's passed, a cycle run.

—Lydia A. Richards.

Thus it is sung in poetry and told in story. Geographers and navigators have always thought there must be an open polar sea. Why? Because if such did not exist, the earth would become loaded with ice

and finally topple over. As it does not topple, but, on the contrary, seems stationary, there must be an open polar sea which serves as an outlet for the surplus ice. This is good logic; but why not apply it to the past as well as to the present? It is a poor rule that will not work both ways. Was there always an open polar sea? If there ever was a time when that sea was closed, then by the same logic the earth at that time must have toppled. We should look backwards and try to ascertain if the same conditions which, if now present, would cause the earth to topple over, have not existed in the past; or search for evidence that might show that it has toppled and readjusted itself.

The idea that it would require an open sea to keep the polar regions from becoming overloaded with ice in order to prevent the earth from toppling over is correct in theory, and will no doubt be found the same in practice. If ever that sea becomes permanently closed — I mean closed to the bottom, so as to prevent cold water from flowing out and distributing itself over the bottom of the general ocean — then as soon as the accumulations of ice become great enough, look out for something to give way similar to the way it did at the commencement of the Champlain Epoch. Look out for another rush — a cataclysm, and a readjustment of the mass of matter to the stable axis of the earth, for such will come as soon as the conditions requiring it fully obtain.

The same forces which buried the Tertiary animals

in Northern Siberia still exist and are still at work, and it is only a question of time until they furnish a like sepulcher for the fauna of the present age. There is no way of judging the future but by the past, and judging by the past, a cataclysm is inevitable whenever the conditions for a readjustment are fully ripe. Look, then, to see the old ocean, which has remained quiet for a long time, suddenly become angry, leave her bed and sweep over the land in great tidal waves, perhaps miles in height, seeking whom she may devour, then at last settling back to a new position, carrying with her the remains of all that had lived in the present age, and burying them as effectually as she did the Tertiary animals in Northern Siberia. Thus will close the present era.

It is not comforting to think that the earth in her old age is subject to such antics, but the evidence as furnished by the Champlain phenomena shows that she has toppled once, and serves as a warning that she is liable to do so again whenever the same conditions exist.

The above is a gloomy picture, yet it also has a bright side. Such destruction is necessary in order that the ice may be cleared away, and the drift region become green again — in order that this land of desolation may become an Eden of beauty. It is nature's method of throwing off for a season the lethargy of death which is stealing over our old planet. If such had not occurred in the past, the greater part of North America and Europe would now be a solitary

waste. Again there is another consolation. By comparing the present accumulations of ice on the earth with those which must have existed during the maximum of the so-called Glacial Period of the past, the time is far distant when another readjustment will become necessary. Therefore, the present generation and those to follow for perhaps some thousands of years need not be uneasy on account of it. They will not be here when it comes.

CHAPTER XX.

THE DESTINY OF THE EARTH.

When ice caps began to form around the poles, as explained in Chapter XII., it marked an epoch in the world's geological history that may be called *the beginning of the end.* Ice for the first time became a factor in geological processes. The currents of the ocean — the great distributers of the sun's heat on the surface of the earth — were for a time interrupted, and thus the ice was allowed to accumulate until the shape of the earth and its center of gravity were materially changed. The internal heat had so far subsided and the rock crust of the surface had become so thick and hardened, that it failed to bend beneath its superincumbent load, and thus there was no way left for nature to effect an equilibrium except by the tipping of the earth, as I have shown in Chapter XV., which for a time restored the equilibrium of matter and permitted the currents of the ocean to distribute the sun's heat over the earth's surface, thereby clearing it of ice; but this relief, geologically speaking, was only temporary. The same causes which culminated in a former unbalancing of the earth still exist, and the ice is again accumulating in the polar regions, and will continue to accumulate until another toppling is produced and another equilibrium is restored,

and so this process will go on, one readjustment after another, and at each subsequent one the destruction will be greater and the time required to effect an equilibrium of heat on the earth's surface will be increased. Metaphorically speaking, these readjustments may be designated as the death struggles of our old planet.

It is believed that from the time when a solid crust on the surface of the earth began to form, the quantity of free carbonic acid in the atmosphere has been diminishing. (Although there might have been intervals when from violent seismic action it was somewhat increased.) But as the internal heat of the earth diminishes and the crust becomes thicker and thicker, there will be less and less seismic action to return the carbonic acid, and then the atmosphere will become entirely depleted of this gas. The effect of this will be to thin the atmospheric blanket (as has been shown in Chapter VII.) and lessen its capacity for holding heat and moisture. Then along with this, we must recognize the fact that the amount of available water in the world is diminishing. We have abundance of evidence to show that in earlier geological ages the amount of watery vapor in the atmosphere and water on the earth's surface was very much greater than at present. Where has it gone? It has been absorbed into the rocks and entered into chemical combination with the materials of the earth's crust, and this process is still going on. As the internal heat of the earth recedes, the water will permeate

the rocks deeper and deeper, and unless this process is interrupted, it will be only a question of time until all the water of the oceans will have disappeared and gone into the rocks.

This seems like a remote contingency when three-fourths of the earth's surface is now covered with water, but it must not be forgotten that the polar ice caps will continue to grow in the future as they have in the past, and this process will assist in using up the available water of the world. At present, if it were not for the icebergs which float away from the polar regions, and by so doing relieve the congestion to a certain extent in that quarter, it would be only a short time, geologically speaking, until all the available water of the world would be piled up there permanently in the form of ice. But a time will come when the icebergs will cease to return this water to the ocean, and then all ice formed in those regions will become a permanent fixture. By these two processes, viz.: the absorption of water into the rocks and the growth of polar ice caps, the atmosphere will become depleted of its moisture. At present watery vapor in the atmosphere is the great conservator of heat on the earth's surface. This vapor surrounds the earth like a blanket and retards radiation of the sun's heat. When from any cause the amount of watery vapor in the atmosphere is diminished, the radiation will be correspondingly increased, thereby increasing the cold and assisting ice formation. To continue glacial formation will require water and heat